Report of the
Ontario Council
of Health on

1970
Supplement No. 9

Report of the activities & supplements

Health Care Delivery Systems

Role of Computers in the Health Field

Ontario Department of Health
Honourable A. B. R. Lawrence, M.C., Q.C., Minister

HEALTH CARE DELIVERY SYSTEMS

The Role of Computers In the Health Field

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ONTARIO

REPORT OF THE ONTARIO COUNCIL OF HEALTH

on

HEALTH CARE DELIVERY SYSTEMS

ROLE OF COMPUTERS IN THE HEALTH FIELD

1970

SUPPLEMENT NO. 9

ONTARIO DEPARTMENT OF HEALTH
Honourable A. B. R. Lawrence, M.C., Q.C., Minister

THE ONTARIO COUNCIL OF HEALTH

The Ontario Council of Health was formed in 1966 as the senior advisory body on health matters to the Minister of Health and, through him, to the Government of Ontario. Council submits recommendations designed to support the overall thrust toward improved health services and it serves as a sentinel to ensure effective and economical employment of the human and physical elements required to provide these services.

The members of Council are selected to reflect a reasonable balance of public interest, expert knowledge, experience, and geographic distribution. In keeping with Council's ongoing role, members are appointed for three years on a rotational basis and may be reappointed once.

Council determines its work priorities through assessment of provincial health services requirements, tempered from time to time by more urgent requests. The successful completion of its assignments is dependent upon the able assistance of committees, sub-committees and task forces manned from the ample reservoir of health interest and expertise to be found in individuals throughout Ontario.

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THE ONTARIO COUNCIL OF HEALTH IN 1970

A first "Report on the Activities of the Ontario Council of Health" was published during 1970. It consisted of a summary document with eight separate annexes containing individual committee reports and recommendations as acted upon by Council. The period covered was from Council's formation in 1966 through the calendar year 1969.

SUPPLEMENTS FOR 1970 – GENERAL

The initial report has proven useful to many individuals and groups concerned with the health care of the people of Ontario. It was therefore decided to make available the major committee reports and recommendations which were processed through Council during 1970. This was substantially a continuation of the work initiated during the first report period, relating directly to committees identified in the annexes. Therefore, it was decided to issue the new report in the form of nine separate supplements, of which this document is one. These supplements, cross-referenced to their original annexes by title, are listed below:

Supplement No. 1
Regional Organization of Health Services
Part II – A Proposed System

Supplement No. 2
Health Statistics
Part II – Implementation of a Health Statistics System

Supplement No. 3
Health Manpower
A. The Need for Family Physicians and General Practitioners for the Province of Ontario
B. Assistance for the Primary Care Physician

Supplement No. 4
Library and Information Services
Library Personnel, Manpower and Education

Supplement No. 5
Health Care Delivery Systems
Community Health Care

Supplement No. 6
Health Care Delivery Systems
Rehabilitation Services

Supplement No. 7
Health Care Delivery Systems
Laboratory Systems

Supplement No. 8
Health Care Delivery Systems
Dental Care Services

Supplement No. 9
Health Care Delivery Systems
Role of Computers in the Health Field

1970 SUPPLEMENT – ROLE OF COMPUTERS IN THE HEALTH FIELD

The Sub-committee on the Role of Computers in the Health Field presented its report to the Committee on Health Care Delivery Systems and the Ontario Council of Health in January 1970. Council approved the recommendations as set forth in this report.

In essence the report describes a province-wide system for the management of health information wherever generated, whether in an office, laboratory, hospital, or community centre. The fundamental unit of information in this system is held to be the individual, for whom a synoptic health record will accumulate his total health experience. Another important feature of the proposed system is that, with due regard for the right of privacy, data shall be held as near the point of creation as possible and yet offer accessibility appropriate to the needs of the users of the system.

The system will not occasion any addition to the mass of health data already collected and maintained. Rather, it will allow for the integration of existing fragmented records and patient detail within the framework of a unified health informational system. The evolutionary implementation of this proposed system is based on the application of systems analysis techniques to the improvement of

information flow and utilization. Implicit in systems analysis is the delineation of the optimal data gathering and processing procedure, having consideration for cost as well as effectiveness.

The Sub-committee is currently addressing itself to the factors which must be considered in evaluation and implementation of such a system.

OTHER AREAS OF COUNCIL ACTIVITY

It will be noted that 1970 supplements to three annexes of the first report have not been issued – Physical Resources, Education of the Health Disciplines, and Health Research:

Physical Resources

In the original annex, the Committee reviewed the current situation and the related services in Ontario which affect physical resources; it highlighted some of the difficulties which exist with respect to the components of the present pattern and made certain recommendations. This completed Council action in this important area, at this stage.

Education of the Health Disciplines

Continued study has been carried out by the Committee. This has been directed primarily toward assessment of the educational requirements for the rehabilitation disciplines and a further report in the area of nursing education. These documents will be completed for presentation to Council in 1971.

Health Research

The Committee on Health Research has continued its work on the definition of the provincial role in health research. It has been devoting its attention particularly to such areas as the economics of health research; the co-ordination of health research programmes within the province, sponsored by both governmental and voluntary agencies; and the personnel support requirements needed to maintain a viable health research programme. It is anticipated that these matters will be completed in 1971.

The Committee has continued to provide direct advice to the Province on applications for financial assistance, through its

Sub-committees on Research Grants Review and Demonstration Models.

During 1970, the Council initiated activity and is developing reports in the following areas:

Audio Visual Systems

The Sub-committee on Audio Visual Systems began work in March, looking into provincial requirements for instructional media systems in the education of the health disciplines, health services, and public health education.

Perinatal Problems

The Sub-committee on Perinatal Problems was established in May to give consideration to problems surrounding birth and affecting either/or mother and infant, and developing proposals for improved health services in this area.

Environmental Quality

A primary Committee on Environmental Quality was set up in October to make recommendations to the government on all matters related to the quality of the human environment, with special consideration to the health and well-being of people.

Future Arrangements for Health Education

In November, Council approved the establishment of a task force to investigate the need for a new medical school/health sciences centre, giving due consideration to new approaches to health education. The relation of health education to health services and the effect of this on the community, not the projected manpower requirements alone, will provide the basis for the study.

Two other undertakings by Council should be noted:

Committee on the Healing Arts Review

A special request was made to Council in June to review the Report of the Committee on the Healing Arts. A review group was

established and it reported to Council in November. It proposed certain basic principles related to the regulation and education of the health disciplines and these, as approved by Council, were submitted to the Minister of Health.

Conference on Co-operation in the Provision of Health Services

In April, Council took an active part in a Conference on Co-operation in the Provision of Health Services, sponsored by provincial bodies representing the various health disciplines, consumers, and the Department of Health. In the public interest, it is Council's policy to consult freely with representatives of health professions, related organizations, and others who share the common bond of seeking the best possible health services for the people of Ontario. This process also occurs as part of the work of the committees of Council.

MEMBERS OF COMMITTEE ON HEALTH CARE DELIVERY SYSTEMS

Dr. K. C. Charron, Chairman	Deputy Minister of Health
Miss C. Aikin	Dean, School of Nursing, The University of Western Ontario
Mr. R. Auld	Executive Director, Ontario Society for Crippled Children
Dr. E. H. Botterell	Dean, Faculty of Medicine, Queen's University
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Dr. T. L. Jones	Ontario Veterinary College, University of Guelph
Dr. R. I. Macdonald	Consultant in Medicine, Toronto
Mr. S. W. Martin	Chairman, Ontario Hospital Services Commission
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Mr. G. W. Phelps	Orillia. Formerly President, Ontario Hospital Association
Mr. F. A. Wilson	Vice-President, Parke and Parke Limited

MEMBERS OF THE SUB-COMMITTEE ON THE ROLE OF COMPUTERS IN THE HEALTH FIELD

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Dr. R. S. Julius	Director, Division of Medical Computing, Faculty of Medicine, University of Toronto
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ACKNOWLEDGEMENTS

The Chairman and Members of the Sub-committee would like to express their appreciation to Dr. G. W. Reid and the staff of the Research and Planning Branch of the Department of Health for their co-operation and assistance during the development of this report; to Mr. L. Fazekas, Systems Co-ordinator, Management Analysis Branch, Department of Health, for his valuable contributions during meetings of the Committee; and to Miss N. I. Grigg, Director of Statistical Research Division, Ontario Hospital Services Commission, for her specialist support.

Particular appreciation must be directed towards Dr. J. R. Smiley, Senior Research Officer (Biostatistics), Research and Planning Branch, Department of Health, who not only provided a major contribution to the preparation and writing of this report but also effectively guided the Sub-committee through numerous intra-governmental complexities.

Acknowledgement must also be given to Mr. W. F. J. Anderson, Executive Secretary, Ontario Council of Health, for his co-operation and advice, and a special accord for the unstinting help of our Secretary, Mrs. J. L. Pearson.

TERMS OF REFERENCE

In the past ten years there have been significant advances and rapid growth in the science of information handling and in computer technology. Present and future capabilities associated with developments in these fields provide a potential of major advantage to the health needs and services of the province. This potential is generally recognized by the health community, some segments of which have already instituted and others are in process of instituting information systems based on computer facilities. The full potential of the science of information handling and of computer technology related to the health field can only be realized by an orderly implementation which takes cognizance of probable future developments. Orderly implementation predicates prior evaluation of present and future installations and systems in terms of the objectives to be achieved and their relative priorities.

To this end, the Ontario Council of Health recommended the creation of a Sub-committee on the Role of Computers in the Health Field, under the aegis of the Committee on Health Statistics. The Sub-committee was "to study the role and potential use of computers in the health field" and "to develop recommendations relating to the distribution of different types of computers within the health facilities to best serve the population and for best utilization of available computer capacity." As a result of the Ontario Council of Health meeting, June 1969, the Sub-committee on the Role of Computers in the Health Field has been placed under the aegis of the Committee on Health Care Delivery Systems.

Recommendations

RECOMMENDATIONS
Supplement No. 9
HEALTH CARE DELIVERY SYSTEMS ROLE OF COMPUTERS

COUNCIL ACTION

The Ontario Council of Health has approved the recommendations of the 1970 report of the Sub-committee on the Role of Computers in the Health Field. However, in accepting the recommendations, the Council recommended that the features of protection of privacy and legal aspects be thoroughly explored, and that the various proposals be thoroughly reviewed with the Committee on Health Statistics of the Ontario Council of Health, so as to ensure development of a coherent system.

RECOMMENDATIONS

System Concept

1. THAT the ultimate objective of the Province, in the area of application of computer technology to health care delivery, be the orderly development of a total health information system.

2. THAT the primary orientation of the system be toward the needs of the individual citizen and not toward the needs of a health care facility, government agency, or other organization.

3. THAT development of the system be based on establishment of lifetime personal health records for each provincial resident, and establishment of derivative and externally created banks of health related information.

4. THAT the system, in terms of both data base and operation, strive to meet the needs of all participants, public and private.

Operational Principles

5. THAT optimal use of the data base be ensured by application of data linkage techniques to sources of information both inherent in and external to the system.

6. THAT original source information which provides the data base be acquired, recorded and organized into an accessible form as close to the time and place of its generation as possible.

7. THAT all files of health related information, wherever possible, be made accessible to the system, whether or not they are generated within the existing system of health care services.

8. THAT, concurrent with the ultimate development of the total health information system, every health facility, agency, and individual participant, where authorized, be provided access to the system.

System Organization

9. THAT the system be compatible with and support regionalization of health care.

10. THAT the functional organization of the system be based on a three-level structure comprising the linkage control centre, one regional centre for each region, and various district centres where districts have been formally established; and that subsystems such as multi-hospital information systems or health sciences information systems should not be accorded independent district status.

11. THAT the principle of dual authority be accepted, whereby responsibility for personnel and administrative procedures be divorced from responsibility for policy, co-ordination, and functional operation.

12. THAT authority for development of policy, co-ordination, and functional operation be vested in a small executive body, which for the purposes of this report is referred to as the central secretariat.

13. THAT the functions of the central secretariat include the following:

    (a) co-ordinating the activities and operation of the system, including both computer services and information management;

    (b) determining the requirements for compatibility, standardization, and quality of performance;

(c) ensuring implementation of administrative decisions pertaining thereto;

(d) co-ordinating requests for data compilation.

14. THAT the central secretariat be assisted by an advisory council, comprising representatives from the regions and other participating agencies, which advises on policy matters and distribution of resources.

15. THAT bodies analogous to the central secretariat and the advisory council be created at regional and district levels, as shown in Appendix E.

Linkage Control Centre

16. THAT the functions of the linkage control centre comprise:

(a) interlinkage of the regional centres with the Department of Health, and with external agencies;

(b) transfer of personal and general health information between districts;

(c) compilation of statistical information from regional centres for onward transmission to the central secretariat.

17. THAT the data base of the linkage control centre be in the form of a computer mediated index in which will be recorded, in a randomly accessible form, the full name, birth date, sex, and a unique code for each provincial resident.

18. THAT the universal unique individual code necessary for efficient data linkage be the Social Insurance Number, and that arrangements be made for the provision of this number to all residents.

Regional and District Centres

19. THAT the data base at a regional centre comprise information resource banks, statistical files for routine operation of the region, and statistical files for routine planning at regional and central levels.

20. THAT the regional centre meet the needs of the regional health council and distribute information to and from central and district levels. Its functions should include collection, assembling, processing, and reporting of pertinent information such as:

    (a) support of regional laboratory system as required;

    (b) support of health resource library system;

    (c) support of educational programmes in the health sciences centres and in the community;

    (d) support of research for health sciences centres and other agencies as required;

    (e) development and maintenance of information resources banks (pharmacopoeia, etc.);

    (f) support of special services (e.g., blood bank, poison control centre, etc.).

21. THAT the data base for the district centre include the following:

    (a) personal data file (PDF) for each resident;

    (b) statistical files for routine operation of the district;

    (c) statistical files for prospective data collection as required by higher levels.

22. THAT the functions of the district centre include the following:

    (a) acquisition, storage, processing, distribution, and maintenance of the PDF for each resident;

    (b) provision of access to the PDF for authorized health personnel;

    (c) provision of information to meet the needs of the district health council and of health personnel;

    (d) collection and distribution of statistical information;

    (e) eventual provision of data storage and computer services for

health personnel and health facilities within the district, as required.

Access to Information and Protection of Privacy

23. THAT a special group, the privacy committee, be formed to deal with matters pertaining to access to and disclosure of personal information, with functions to include the following:

    (a) definition of the level of access permitted to different classes of users of the system;

    (b) definition of standards of disclosure of information;

    (c) standardization of procedures of access and disclosure of information, including a means of bypassing normal rules and restrictions in an emergency;

    (d) provision of advice to the central secretariat on the accreditation of qualified investigators for special research involving the disclosure of identity;

    (e) provision of advice to the central secretariat on the desirability of research involving the disclosure of identity;

    (f) provision of advice to the central secretariat on special requests not covered by established procedures.

24. THAT, if anonymity is preserved, access to information should be relatively simple and easy.

25. THAT physicians have access to the PDF of their patients.

26. THAT the written consent of the person or his legal representative be obtained by the central secretariat before identifying information is disclosed to a research investigator: however, if the investigator provides adequate guarantees that he would use identifying information only for purposes acceptable to the privacy committee, e.g., to link data between existing files for purposes of statistical analysis, and would maintain the information so obtained in a manner acceptable to the privacy committee, then this procedure would be waived.

27. THAT the rules and standards of disclosure be made known to

the public.

28. THAT the individual have right of access to his own file to verify or modify it, with the proviso that any modified or deleted item be flagged appropriately so long as flagging per se does not compromise the privacy of the individual.

29. THAT all single, unique, non-statistical accession to files be recorded in the PDF.

30. THAT computer personnel working within the health information system be licensed.

Reliability, Protection and Disposal of Records

31. THAT a set of procedures be adopted which attempt to guarantee the reliability of the information in the system. In addition to a continuing audit, these procedures should include source data checking, verification of transcriptions, and computer check procedures.

32. THAT a set of procedures be adopted which are in accordance with generally accepted techniques for the preservation of basic data: namely, that at least three generations of data bank be retained with all associated updating information; that standby units which can provide skeleton operations be installed; and that an updated copy of the software with full documentation be kept in a separate fireproof location.

33. THAT, in the light of modern data processing, consideration be given toward defining what information will be kept, in what form, and for how long.

Personnel

34. THAT the planning of the health information system encompass the recruiting and, where necessary, the training of highly competent information scientists, systems analysts, programmers, computer technicians, electronic data processing managers, and clerical staff.

Planning and Implementation

35. THAT a planning group be formed, comprising persons whose

joint skills and experience cover the following areas: delivery of health care, systems analysis, information processing, and economic analysis.

36. THAT the planning group be directly responsible to the Deputy Minister: that its members be non-voting members of the Sub-committee on the Role of Computers in the Health Field.

37. THAT the Sub-committee on the Role of Computers in the Health Field continue to report to the Ontario Council of Health throughout the implementation of the system.

38. THAT the function of the planning group include the following:

    (a) determination of the needs of the users;

    (b) provision of advice on the organizational structure appropriate to the health information system;

    (c) consideration of methods and costs of implementing the system in its early phases;

    (d) definition of manpower, software, and hardware needs.

39. THAT a comprehensive, specific, and detailed definition and documentation of the health information needs of the Province, already initiated, be continued and expanded by the planning group.

40. THAT an analysis and documentation be carried out on those procedures currently extant which attempt to meet these needs, with particular reference to the requirements of the physician and allied health personnel in the delivery of primary health care.

41. THAT the detailed design of the health information system be based on the information gathered and documented in Recommendations 39 and 40 above.

42. THAT an appropriate staff of systems analysts, programmers, technicians and clerks be provided to the planning group.

43. THAT, as a primary step in the implementation, a pilot project be initiated within a district or smaller geographical area containing a health sciences centre, and that development of

other districts within that region take place in an evolutionary manner concurrent with development of regional facilities and before extension to other regions.

Report of the Sub-committee on the Role of Computers in the Health Field

SECTION I

Summary

The following is largely a transcription of the Interim Report on the Role of Computers in the Health Field presented to the Ontario Council of Health in October 1969.

The substance of the report is a proposal for a total health information system for the Province encompassing all areas of patient management, community health, planning, administration, education, and research. As will be seen, this proposal is unique in its scope.

The deliberations of the Sub-committee were predicated on a number of beliefs. Some of the more fundamental were: that the demand for high quality health care will continue to increase throughout the province; that all residents within Ontario are entitled to the same high quality health care unimpeded by socio-economic, geographic, and other inhibiting factors; that social and economic pressures are urging the integration of health care throughout the community; that the trend toward the increase in use of laboratory technology, physiological test and management procedures, mass-screening, etc., will lead to an increased demand on the skills and time of health workers; and that there is an increasing demand on the part of the planner and administrator for meaningful and timely information. Furthermore, it is apparent that data vital to the implementation of total health care are generated continuously and in vast amounts, but are commonly used only for limited, specific, and local purposes. The larger purpose cannot be achieved until these data can be assessed, linked, collated, processed

and otherwise rendered into understandable and timely information.

THE INFORMATION SYSTEM

The physician, the planner, and the administrator are therefore faced with two related problems: a plethora of data, and an encumbrance of routine paperwork for manual management of this data. The absence of a co-ordinated structure for health data management precludes optimum use of computer technology. Realizing this, the Sub-committee then perforce turned its attention to the needs of a health information system, the subject of this report. A health information system is considered to be a coherent, interconnected, readily accessible body of knowledge pertaining to health care, along with the physical means, organization, personnel, and procedures, by which that information is acquired, processed, stored and distributed.

In pursuance of this objective of a total health information system, the Sub-committee investigated existing and proposed information systems. All were found to have major restrictions and tended to be facility rather than patient oriented. Further discussions led us to the contrary conclusion that a total system must be centered on the individual. As a result, the Sub-committee has devised a conceptual system based upon the creation of a lifetime personal data file for each Ontario resident, which will be held at community level and linked to other sources of health and health-related information. It is considered that this system will meet the information requirements set out in the recommendations of the Committee on Health Statistics.

An immediate consequence of an information system based on the life experience of the individual is that the practising physician and, in particular, the first contact physician, can obtain on request the complete medical history of each patient, including new patients, in detail sufficient for his purpose. Because of the organizational structure of the proposed system, he can readily obtain not only an overall summary of an individual's past history, but also, for example, a detailed report of a period of hospitalization. Likewise, because the system is based on the total experience of the individual, the epidemiologist can measure trends and relationships over longer periods of time and for larger samples. The medical officer of health can more readily detect the onset of local epidemiological problems and take appropriate action. Long term measures of the efficacy of treatment or of operative procedures can be more easily obtained

and assessed. Patterns of health care and of utilization of health manpower can be delineated, permitting optimum deployment of resources and timely modification of the manpower training programme. The literature is replete with reports of applications to hospital patient care and hospital management. Other obvious benefits of the system lie in the development of pharmaceutical, physiological, and laboratory data banks oriented specifically to the needs and usage of local areas.

ROLE OF COMPUTER TECHNOLOGY

Implementation of a sophisticated health information system of this type, with a resulting improvement in the quality of health care, demands the resources of a highly developed computer technology which are only now becoming available. At the same time, it is emphasized that the computer is merely a tool for mass information management; it is not the system itself, and its use is contemplated only for those purposes where its superiority over other methods has been demonstrated. There are four major activities in an information system to which this technology can be applied, namely, the acquisition, storage, processing, and distribution of information.

Acquisition of health data, as currently practised, is almost entirely manual. The Sub-committee, however, is cognizant of changes presently occurring in methods of data acquisition, such as optical scanning, mark sensing, and magnetic sensing, and has discussed their incorporation into a system for health data acquisition as they evolve into commercially proven techniques. The functions of storage and processing have long been within the province of computer technology, although the techniques for readily accessible storage of information in the volume required by the health services have only recently become available and await exploitation. The Sub-committee had discussed and will indicate how this exploitation might be approached. Computer technology can also provide a method for data distribution, but most certainly does not present the only way, nor is it proposed to employ the computer as the sole or even the primary distributor of data. Urgency of need for information must determine the mode of data distribution, whether it be manual, mail, teleprinter, microwave, on-line computer, etc.

As another point of emphasis, it must not be assumed that a considerable increase in data acquisition must accompany the development of the proposed system. This is neither the intent, nor will it be the outcome. The data are already existent, fragmented and

compartmentalized. The principal objective of the system is to increase the accessibility of the data already available, to assure timeliness, and improve the mode of presentation. As the system evolves, it will, in fact, lead to a critical reappraisal of the nature of the data to be collected, and the use to which it will be put.

LEGAL ASPECTS

Considerable attention has been paid to the legal ramifications of the system. In particular, it is believed that access to the proposed system should be controlled and made available only to authorized persons. Very special care must be exerted in making available personally identifiable data. As a corollary, one conclusion in particular holds that the individual must have access to and exert jurisdiction over the content of a personal medical record in which he can be identified by name or number within the system.

ORGANIZATION

The organization of the proposed health information system is compatible with the three-tier system recommended by the Committee on Regional Organization. The nature of the system is such that the bulk of the data must be held at the periphery, that is, at district or community level, largely in the form of a personal data file, with linkage to hospital, laboratory, public health, and other pertinent records. At the same time, administrative and planning functions of government necessitate a regional level of information. The system, therefore, envisages a regional centre which processes district data, provides a switching function for data linkage both intra- and inter-region, and compiles data for community, regional, and provincial use. In addition, the regional data bank will store general planning, administrative, and professional data pertinent to the needs of the region. Finally, at the central level, the Sub-committee proposes a linkage control centre with a dual function computer facility comprising a citizen's index register, which is the core of the system's total linkage capability, and a processing facility for provincial use.

IMPLEMENTATION

The Sub-committee emphasizes that it does not intend to recommend instantaneous imposition of a total system of this magnitude. The system is such that phased development and implementation will be quite feasible within the present state of the art.

Recommendations to this end are included herein.

In conclusion, it is the opinion of the Sub-committee that the application of computer technology to health care services is not only mandatory but inevitable. It is also very expensive and consequently the Sub-committee is extremely sensible of the fact that the application of computer techniques must proceed with wise caution, careful co-ordination, and the participation of all levels of management under the guidance of a carefully established policy.

SECTION II

Recommendations

Consideration of the needs and implementation of a total health information system gives rise to a number of recommendations. These recommendations fall naturally into logical groupings as presented below.

SYSTEM CONCEPT

(pages 83-89; see also pages 63, 97)

The information available for use in the delivery of health care has been traditionally based on personal medical records and on the data by-products of personal medical records, health insurance programmes, and government planning, the organization of which is inadequate to meet the overall needs of the patient and of the purveyor of health care, and does little to provide for banks of information resources for other health care use. As each programme or facility has been created, it has generated a data system oriented to its administrative requirements. It is our firm opinion that the time is propitious for the development of a plan to organize information for the direct benefit of all health workers, particularly those who operate in the area of first contact medicine.

Information science and computer technology have now reached a stage where an information system of this nature has become feasible.

It is therefore recommended:

RECOMMENDATION 1
THAT the ultimate objective of the Province, in the area of application of computer technology to health care delivery, be the orderly development of a total health information system.

RECOMMENDATION 2
THAT the primary orientation of the system be toward the needs of the individual citizen and not toward the needs of a health care facility, government agency, or other organization.

RECOMMENDATION 3
THAT development of the system be based on establishment of lifetime personal health records for each provincial resident, and establishment of derivative and externally created banks of health related information.

RECOMMENDATION 4
THAT the system, in terms of both data base and operation, strive to meet the needs of all participants, public and private.

OPERATIONAL PRINCIPLES
(pages 66, 83-89)

The Sub-committee considers it important that the data base of the system ultimately incorporate *all* health and health related data, whether generated by the patient, by government departments, or by other agencies. It considers also that the information so generated must be captured as close to the time and place of its generation as possible. The full potential of an information system can only be realized when one file can be correlated with another. Hence the key to information management lies in record linkage.

It is therefore recommended:

RECOMMENDATION 5
THAT optimal use of the data base be ensured by application of data linkage techniques to sources of information both inherent in and external to the system.

RECOMMENDATION 6
THAT original source information which provides the data base be acquired, recorded and organized into an accessible form as close to the time and place of its generation as possible.

RECOMMENDATION 7
THAT all files of health related information, wherever possible, be made accessible to the system, whether or not they are generated within the existing system of health care services.

RECOMMENDATION 8
THAT, concurrent with the ultimate development of the total health information system, every health facility, agency, and individual participant, where authorized, be provided access to the system.

SYSTEM ORGANIZATION
(pages 84-87, 95, 96 and Appendix E)

Owing to the diversity of interests of the participants in the system, normal departmental management procedures are inapplicable. It is therefore necessary to consider an organizational structure incorporating the interests of all while remaining compatible with the concepts of regionalization. The relevant recommendations from the Report to Council by the Committee on the Regionalization of Health Services have been accepted as basic premises and incorporated into the proposed organization to provide for the needs of regional and district government.

It is therefore recommended:

RECOMMENDATION 9
THAT the system be compatible with and support regionalization of health care.

RECOMMENDATION 10
THAT the functional organization of the system be based on a three-level structure comprising the linkage control centre, one regional centre for each region, and various district centres where districts have been formally established; and that subsystems such as multi-hospital information systems or health

sciences information systems should not be accorded independent district status.

RECOMMENDATION 11
THAT the principle of dual authority be accepted, whereby responsibility for personnel and administrative procedures be divorced from responsibility for policy, co-ordination, and functional operation.

RECOMMENDATION 12
THAT authority for development of policy, co-ordination, and functional operation be vested in a small executive body, the central secretariat.

RECOMMENDATION 13
THAT the functions of the central secretariat include the following:

(a) co-ordinating the activities and operation of the system, including both computer services and information management;

(b) determining the requirements for compatibility, standardization, and quality of performance;

(c) ensuring implementation of administrative decisions pertaining thereto;

(d) co-ordinating requests for data compilation.

RECOMMENDATION 14
THAT the central secretariat be assisted by an advisory council, comprising representatives from the regions and other participating agencies, which advises on policy matters and distribution of resources.

RECOMMENDATION 15
THAT bodies analogous to the central secretariat and the advisory council be created at regional and district levels, as shown in Appendix E.

LINKAGE CONTROL CENTRE (pages 57, 66, 84-88)

The Sub-committee believes that the provincial level of the system should not be permitted to become a giant information management complex, subsuming unto itself the needs of data processing throughout the province. It considers that departments and other arms of government should continue to hold and develop such files as their needs require, so long as the files are accessible and linkable to other files within the system. It follows that the information system at provincial level requires only a register of provincial residents, which will permit linkage and switching of personal data files, along with limited data processing capability.

To ensure positive identification, it is apparent that provision must be made for assignment to each provincial resident of a unique individual code which will be included in all identifiable personal documents and used in the central registry.

It is therefore recommended:

RECOMMENDATION 16
THAT the functions of the linkage control centre comprise:

(a) interlinkage of the regional centres with the Department of Health, and with external agencies;

(b) transfer of personal and general health information between districts;

(c) compilation of statistical information from regional centres for onward transmission to the central secretariat.

RECOMMENDATION 17
THAT the data base of the linkage control centre be in the form of a computer mediated index in which will be recorded, in a randomly accessible form, the full name, birth date, sex, and a unique code for each provincial resident.

RECOMMENDATION 18
THAT the universal unique individual code necessary

for efficient data linkage be the social insurance number, and that arrangements be made for the provision of this number to all residents.

REGIONAL AND DISTRICT CENTRES
(pages 58, 85-93)

In the absence of definitive information pertaining to the regionalization of health care, it is not possible to predict with certainty the system function at these levels. The Sub-committee believes, however, that even if regionalization is not implemented in the near future the information system itself will function best if organized on a regional basis.

It is therefore recommended:

RECOMMENDATION 19
THAT the data base at a regional centre comprise information resource banks, statistical files for routine operation of the region, and statistical files for routine planning at regional and central levels.

RECOMMENDATION 20
THAT the regional centre meet the needs of the regional health council and distribute information to and from central and district levels. Its functions should include collection, assembling, processing, and reporting of pertinent information such as:

(a) support of regional laboratory system as required;

(b) support of health resource library system;

(c) support of educational programmes in the health sciences centres and in the community;

(d) support of research for health sciences centres and other agencies as required;

(e) development and maintenance of information resources banks (pharmacopoeia, etc.);

(f) support of special services (e.g., blood bank, poison control centre, etc.).

RECOMMENDATION 21
THAT the data base for the district centre include the following:

(a) personal data file (PDF) for each resident;

(b) statistical files for routine operation of the district;

(c) statistical files for prospective data collection as required by higher levels.

RECOMMENDATION 22
THAT the functions of the district centre include the following:

(a) acquisition, storage, processing, distribution, and maintenance of the PDF for each resident;

(b) provision of access to the PDF for authorized health personnel;

(c) provision of information to meet the needs of the district health council and of health personnel;

(d) collection and distribution of statistical information;

(e) eventual provision of data storage and computer services for health personnel and health facilities within the district, as required.

ACCESS TO INFORMATION AND PROTECTION OF PRIVACY
(pages 59, 77-82; see also page 89)

The main feature of the health information system is the PDF, which holds lifetime information on all persons, and should be accessible to many agencies and individuals. It is imperative therefore to protect the privacy of individuals without inhibiting unnecessarily the potential for improving health care delivery, research, and government planning. Privacy only becomes a problem when the person can be identified through information released from the files.

Unfortunately, there is no clear-cut way by which one may

distinguish those who may have access to personally identifiable information from those who may not. For this reason, the Sub-committee proposes the establishment of a special group who would be concerned with rules and standards of access and appropriate legislation. Nonetheless, there are specific rules and standards which will be recommended at this time.

It is therefore recommended:

RECOMMENDATION 23
THAT a special group, the privacy committee, be formed to deal with matters pertaining to access to and disclosure of personal information, with functions to include the following:

(a) definition of the level of access permitted to different classes of users of the system;

(b) definition of standards of disclosure of information;

(c) standardization of procedures of access and disclosure of information, including a means of bypassing normal rules and restrictions in an emergency;

(d) provision of advice to the central secretariat on the accreditation of qualified investigators for special research involving the disclosure of identity;

(e) provision of advice to the central secretariat on the desirability of research involving the disclosure of identity;

(f) provision of advice to the central secretariat on special requests not covered by established procedures.

RECOMMENDATION 24
THAT, if anonymity is preserved, access to information should be relatively simple and easy.

RECOMMENDATION 25
THAT physicians have access to the PDF of their patients.

RECOMMENDATION 26
THAT the written consent of the person or his legal representative be obtained by the central secretariat before identifying information is disclosed to a research investigator: however, if the investigator provides adequate guarantees that he would use identifying information only for purposes acceptable to the privacy committee, e.g., to link data between existing files for purposes of statistical analysis, and would maintain the information so obtained in a manner acceptable to the privacy committee, then this procedure would be waived.

RECOMMENDATION 27
THAT the rules and standards of disclosure be made known to the public.

RECOMMENDATION 28
THAT the individual have right of access to his own file to verify or modify it, with the proviso that any modified or deleted item be flagged appropriately so long as flagging per se does not compromise the privacy of the individual.

RECOMMENDATION 29
THAT all single, unique, non-statistical accession to files be recorded in the PDF.

RECOMMENDATION 30
THAT computer personnel working within the health information system be licensed.

RELIABILITY, PROTECTION AND DISPOSAL OF RECORDS
(pages 81-82)

Without careful and continuous checking, it is inevitable that errors in information content will occur in the data retained in the system files. A continuing audit is therefore necessary. While direct individual check would be ideal, the resulting expense would be unacceptable. Suitable sampling procedures can, however, be devised.

As the system develops, increasing reliance will be placed on it by users who will expect continuous and reliable operation. It is therefore imperative that the integrity of the system be maintained in the face of damage, loss, or power failure. The data base must be capable of being reconstructed within some specified time period. Where real-time operation is a requirement, special effort must be made to ensure uninterrupted operation.

It is also necessary to provide for formal destruction of records after a suitable period. Consideration must be given toward defining what information will be kept, for how long, and in what form.

It is therefore recommended:

> *RECOMMENDATION 31*
> *THAT a set of procedures be adopted which attempt to guarantee the reliability of the information in the system. In addition to a continuing audit, these procedures should include source data checking, verification of transcriptions, and computer check procedures.*
>
> *RECOMMENDATION 32*
> *THAT a set of procedures be adopted which are in accordance with generally accepted techniques for the preservation of basic data: namely, that at least three generations of the data bank be retained with all associated updating information; that standby units which can provide skeleton operations be installed; and that an updated copy of the software with full documentation be kept in a separate fireproof location.*
>
> *RECOMMENDATION 33*
> *THAT, in the light of modern data processing, consideration be given toward defining what information will be kept, in what form, and for how long.*

PERSONNEL
(page 89)

The personnel needs of the health information system cannot be projected with accuracy until plans for the system have been developed in more detail. Nonetheless, the need for personnel should

be regarded as a priority item because the demand for skilled people will strain manpower resources to the limit.

It is therefore recommended:

> *RECOMMENDATION 34*
> *THAT the planning of the health information system encompass the recruiting and, where necessary, the training of highly competent information scientists, systems analysts, programmers, computer technicians, electronic data processing managers, and clerical staff.*

PLANNING AND IMPLEMENTATION
(pages 95-96; see also pages 54, 62, 65, 78, 83, 85 and 88)

The deliberations of the Sub-committee, culminating in the foregoing recommendations, have been concerned with development of the *concept* of a health information system. To translate the concept into an effectively operating organization will require the full-time effort of a group of individuals specially selected for the purpose. The detailed analysis of personnel, software, and hardware requirements cannot be effectively handled by an extramural committee, however dedicated. The group so formed will need to be experienced and skilled in a variety of fields, with knowledge and understanding not only of the needs of health care delivery but also of the problems of manpower and economics, systems development, and the limitations and capabilities of information systems in particular. The emphasis in selection should be on skills needed rather than professional affiliation, although representatives of different professions will be required.

It is also agreed that implementation of the system must take place in an evolutionary manner, beginning with a suitable pilot project and progressing to an ultimate total involvement.

The group should be so organized that it is responsible to the Deputy Minister of Health, and it should be assisted in its operation by the existing Sub-committee on the Role of Computers in the Health Field.

It is also clear that in order, ultimately, to achieve the health information system described, it will be necessary to define in detail the health information needs of the Province, to identify and document explicitly the present methods of attempting to meet

these needs, and to design the health information system in detail in accordance with the structure and other recommendations of this report. It should be noted that these three tasks are interdependent and therefore should proceed concurrently as part of the first charge to the planning group.

It is therefore recommended:

RECOMMENDATION 35
THAT a planning group be formed, comprising persons whose joint skills and experience cover the following areas: delivery of health care, systems analysis, information processing, and economic analysis.

RECOMMENDATION 36
THAT the planning group be directly reponsible to the Deputy Minister: that its members be non-voting members of the Sub-committee on the Role of Computers in the Health Field.

RECOMMENDATION 37
THAT the Sub-committee on the Role of Computers in the Health Field continue to report to the Ontario Council of Health throughout the implementation of the system.

RECOMMENDATION 38
THAT the function of the planning group include the following:

(a) determination of the needs of the users;

(b) provision of advice on the organizational structure appropriate to the health information system;

(c) consideration of methods and costs of implementing the system in its early phases;

(d) definition of manpower, software, and hardware needs.

RECOMMENDATION 39
THAT a comprehensive, specific, and detailed definition and documentation of the health information needs of the Province, already initiated, be continued and expanded by the planning group.

RECOMMENDATION 40
THAT an analysis and documentation be carried out on those procedures currently extant which attempt to meet these needs, with particular reference to the requirements of the physician and allied health personnel in the delivery of primary health care.

RECOMMENDATION 41
THAT the detailed design of the health information system be based on the information gathered and documented in Recommendations 39 and 40 above.

RECOMMENDATION 42
THAT an appropriate staff of systems analysts, programmers, technicians and clerks be provided to the planning group.

RECOMMENDATION 43
THAT, as a primary step in the implementation, a pilot project be initiated within a district or smaller geographical area containing a health sciences centre, and that development of other districts within that region take place in an evolutionary manner concurrent with development of regional facilities and before extension to other regions.

SECTION III

Introduction

The physician, the planner and the administrator are faced with two related problems: a plethora of data, and an encumbrance of routine paperwork for manual management of this data. Realizing these facts, the Sub-committee sought to find a co-ordinated structure for health data management, to which computer technology might be optimally applied within the existing health care delivery system. Failing to find such an organization, it perforce turned its attention to the needs of a health information system, the subject of this report. A health information system is considered to be a coherent, interconnected, readily accessible body of knowledge pertaining to health care, along with the physical means, organization, personnel, and procedures, by which that information is acquired, processed, stored and distributed.

This report is concerned with health information in the Province of Ontario. The substance of the report is a proposal for a total health information system for the Province, encompassing all areas of patient management, community health, planning, administration, education and research. The one identifying criterion for the information under consideration is that it be pertinent, directly or indirectly, to the health field. It includes, then, information as diverse as hospital payroll, patient medical records, laboratory test results for private physicians, immunizing schedules for public health offices, vital statistics for various government agencies, chromosome classification programmes for medical research, and simulation programmes for teaching.

The cost of collecting all such information, of storing it, of manipulating, retrieving and disseminating it, would be prohibitively large even if it were possible; the cost of not doing any of these things is equally excessive. The recommendations embodied in this report attempt to strike a balance between these two extremes.

SECTION IV

General Review of Needs

In the accelerating expansion of today's technology, the term "information explosion" has become almost a cliché. Yet in its medical and paramedical attributes it represents a phenomenon of vital significance to the physician, the health care scientist, and the health care administrator alike. Each tends to be overwhelmed by the magnitude of the task facing him – pressed with demands for an ever increasing scope of health care, defeated by the logistic impossibilities of its implementation, flooded by a mass of data relevant and irrelevant, and all too often lacking the very information necessary for optimum decision making.

This, of course, is not a problem that is confined to the biomedical field. It is of at least equal concern to the other sciences, to business, to military and other government organizations. The beginnings of the computer sciences some twenty years ago, however, provided the tool for channelling and organizing the information generated, and even for controlling the process of generation. But, while other groups have seized upon the capacities of the computer to aid them in solution of their problems, the medical profession, with its traditional and normally wise caution, has been reluctant to explore the usefulness of what has become in other milieu an accepted and necessary approach to problem solution.

Maloney (1966)* states the situation well when he says:

* References are to the bibliography of Section XIV on page 99.

"Whenever a new tool or technique is introduced into medical science there follows a period of examination and evaluation to determine if the new method will achieve its original promise. Such was the case with the aseptic technique, the flame photometer, and radioisotopes. It is rare, indeed, that the physician has been provided with a tool whose power has already been proved by analogous applications in medicine's sister sciences. Such is the case with the digital computer."

One must not infer from this statement, however, that the time is now ripe for immediate application of automation and computer techniques throughout the field of medicine and the health sciences. Very much remains to be done and still more to be explored before one can achieve a happy union between the arts and sciences of medicine and the hardware of the computer. The time is now ripe, however, to examine the total problem, to determine the orientation desirable, and to direct the development of biomedical computer technology through a process of quickened evolution.

Computer arts and science are such that the problem has to be examined in its entirety. For efficiency and economy, computer technology must be embodied in a total system. This does not necessarily mean centralization with autocratic control exerted by one giant cybernetic monster, but it does mean that a conceptual model of the entire system must be examined prior to the development and implementation of any part thereof. It is ineffective to develop the system randomly, even by priority need, without considering the relationship of the areas developed to other areas and to the system as a whole. Such a process would be akin to designing and building the engine, body, wheels, suspension, controls and interior of an automobile as unrelated entities, and subsequently attempting to integrate them into one vehicle.

As Gabrieli (1968a) puts it, "Designing a computer-aided system necessitates a departure from the time-proven research ground rules, where planning is a one-step-at-a-time organization focussing attention and effort on the immediate problem, while attempting to move in the general direction of the ultimate aim. For effective planning of a large computer-aided system, the demands imposed when in full operation must be identified at the outset. A gradual development of software and hardware capabilities must be organized to maintain full compatibility with the projected final operation. Therefore, in planning a large system one has to 'think big' but proceed cautiously. The implementation should be one-step-at-a-time, but the conceptual

system design should be as far as we can see in the future."

Various groups have examined the basic need of medical information systems. Baruch (1968), in particular, points out that one does not design such systems to solve problems in the field of medicine; one designs them for people's perception of those problems. One might go farther than that and suggest that such systems are designed for ease in perception of the problems and for implementation of solutions. He outlines six desirable characteristics of a medical information system, all of which can be met by the use of computer technology.

1. Access speed: The ability to obtain, when necessary, an item of stored information on very short notice.

2. Content reliability: Negligible probability of undetected content errors, including data loss.

3. Record continuity: The ability to store diverse records pertaining to each individual over a prolonged period.

4. Bulk processing ability: The ability to process large masses of data relating to large populations.

5. Modifiability: The ability of the user to modify programmes and data structures in accordance with experience.

6. Training ease: The ability, with minimal effort, to teach the user to benefit from the system.

To these might be added the capacity for record linkage, namely the ready accessibility to diverse records pertaining to an individual but maintained for differing purposes in various locations.

Fundamentally, we are concerned with the acquisition, storage, processing, and retrieval of information in order to extend the resources available to the physician, health scientist, educator, administrator, and planner, for the preservation of health, the delivery of health care, and the treatment of disease. In so doing, we are also concerned with improvement of efficiency of health care systems, in terms of both cost and quality, by organization of procedures and logistics. These aims must be accomplished with sensitivity, specificity, reliability, accuracy, and without undue sacrifice of personal privacy.

Given the resources, trained manpower, and technology, and of these the last named is within sight, the ultimate system, organized on a hierarchical basis, with appropriate record linkages to other private and public sources of information, must contain as the core a life health record of each individual. Additionally, it must contain demographic, environmental, and other technical data, facilities for procedural, logistic, and patient management within the community and the hospital, and provision for access to appropriate data banks to meet the differing needs of diverse users. It is again emphasized that one does not envisage a gigantic centralized system. In fact, it is most probable that separate systems may well evolve, linked by headers and pointers, and incorporating other sources of communication such as the teletype, the telephone, and even an ordinary mail link, depending on priorities. Perhaps the provision of linkages to unite various subsystems and provide ready access to multiple stores of information is the most significant factor in the design of a health information system. Automatic linkage, however, is far from easy and may prove to be a great stumbling block requiring much research and development before it can be implemented.

Aside from linkages to other sources of storage, Baruch (1968), although not emphasizing the need for a life health record, recognizes three facets of a medical information system. The patient-care system would incorporate a collection of small, fast access systems, with great attention paid to the human engineering for each user group, but with no requirement for exceptional files, long-term record stores, complex programming, or extensive processing. For the administrator, however, he sees a requirement for a large business system similar to those in common use in industry. The needs of the researcher would require a system with a massive long-term memory to provide for records of large populations, coupled with high level programming and record configuration languages such as are found in scientific institutions where one deals with matrices of high order, long programmes, and complex displays.

Be that as it may, the ultimate system is still far off, and nowhere as yet has any total system been implemented. It is appropriate at this time, however, to examine the structure of such a system and determine those areas in which computer technology can be applied. It must be emphasized that the digital computer is essentially a device or tool for the storage, processing, and retrieval of information, the output of which may be displayed in various ways, or used to activate other devices. Bearing this function in mind, the Sub-committee has recognized four major functional areas in the

field of health care in which computer technology may be applied, namely, the hospital, the community, government, and research and education. It has also devised, as will be described later, a conceptual model of an integrated health care information system which will meet the needs of each function, so far as can now be seen, in a manner compatible with existing health care systems and potential health care development.

SECTION V

Needs for Computing in the Hospital Environment

The modern general hospital is probably one of the most complex organizations ever developed. Not only is it required to provide functions as varied as those found in units of large industrial corporations, but it has to shelter, feed, and clothe those lodged within, under a wide variety of conditions, and provide, service, and maintain a vast array of equipment, and facilities, while maintaining appropriate sterility and quality control. In addition, its procedures and practices must meet the requirements of routine operation, individual emergency, and catastrophic contingency. It is not surprising that management problems can arise. Even to identify these problems requires a study in depth, which will have to be accomplished before any phased system can be implemented with the proper priorities, but some of the problems, at least in a preliminary examination, can be subsumed under the headings of needs of patient management, needs of research and education, and needs of administration.

PATIENT MANAGEMENT

The term "patient management" is applied to all those activities directly concerned with the provision of medical care, e.g., history taking, special investigations, laboratory testing, medical diagnosis, prescription of drugs, and treatment, and provision of nursing and other care. The link on which all depend is, of course, the medical record, which not only serves that function but acts as a basis for planning and research.

HOSPITAL MEDICAL RECORD

One of the earliest uses of the computer in health care was for the storage and analysis of medical record abstracts. To do so, however, requires that careful consideration be given to the nature of the record itself. One of the primary problems, and one that is applicable to all aspects of a medical information system, lies in identification of the individual concerned. Much consideration has been given to the use of social insurance or social security numbers, birth numbers, and specially generated numbers in which information pertaining to the individual may be coded. Before any system is implemented, some decision will have to be taken with regard to identification numbers. Much consideration has been given to this problem, and while advantages may accrue from many coded numerical systems, or even the standard birth registration number modified to include specially generated numbers for those born outside the country, it is evident that use of the Social Insurance Number is becoming the most commonly accepted procedure for this purpose.

The format of the record requires much consideration. Traditionally, record development has been largely left to the individual practitioners and hospitals, and has led in some cases to habits of record keeping which are neither effective for patient care nor suitable for computerized coding. Lawrence Weed (1968 a, b) has developed a system of "problem oriented" record keeping which is oriented to the needs of both the patient and the computer, whilst various other workers have developed specific logical records highly suitable for computer coding (Gabrieli, 1968 a, Davis, et al, 1968, Gabrieli, 1968 b). The J. Edward Meyer Memorial Hospital in Buffalo, in particular, has developed a whole series of different specialty medical records for this purpose.

One of the major problems of the computerized record lies in the requirement for coding. Barnett (1968), of the Harvard Medical School, in a study of these problems, rightly observes that many of the computer-oriented record designs have required the development of a predefined, rather rigid classification and coding of data, sometimes with loss or distortion of information. These limitations have led to attempts at utilizing free English language, using special compilers to accept this input. This in turn has led to semantic and spelling difficulties and has found successful application only in circumstances where words are used with consistent meaning, as for example in pathology reports. For some time to come, record systems will either have to be pre-phrased in questionnaire form, as is

done at the Edward Meyer Hospital, or the user will have to utilize some recognized terminology derived from works such as the Standard Nomenclature of Diseases, the International Classification of Diseases (A), the Systematized Nomenclature of Pathology, and the rapidly developing Current Medical Terminology. Before implementation of a system, much consideration will have to be given to the nature of the record and the form of standardization to be used.

MEDICAL HISTORY

A significant portion of the medical record is the medical history. Three motives can be recognized for the development of automated systems for history recording and storage, the first being increase in efficiency. Acquisition of an appropriate history takes a significant and expensive portion of physician time and yet still may result in an illegible, incomplete and inadequate record. The second motive lies in the use of comprehensive histories as a screening device in the early detection of disease. It is well recognized that an adequate history is of paramount importance in diagnosis, but all too often the depth of the history-taking is a function of the time available for taking it. Use of the computer to suggest, and even implement, investigative studies after analysis of a comprehensive questionnaire can be a valuable aid in disease detection. A further motive, as suggested by Barnett (1968) is that the technique of automated history-taking will give impetus to the generation of efficient procedures, standardized terminology, and coded information useful for epidemiologic studies and for extension to computer-aided diagnosis.

Although various groups have developed questionnaires which lend themselves to computer application, such as the Cornell Medical Index, the Medical Data Index, the Medical Passport, and the Minnesota Multiphasic Personality Inventory, perhaps the most significant applications have been done by the Permanente group with their Multiphasic Health Checkup, which embodies in a Patient Computer Medical Record not only the results of a very comprehensive history, but also suggestions on further investigation and testing for the advice of the physician (Collen, 1966).

Since, however, there is as yet no clearly established consensus concerning the form that automated history-taking should assume, much care will have to be taken to seek acceptance and compatibility with traditional methods before adopting some specific computer-oriented format.

SPECIAL INVESTIGATIONS

The term "special investigations" is employed to describe the use of laboratory, X-ray, and other bioinstrumental facilities. The field here is so large that, without an evaluation by individual specialists, it is impossible to do more than refer in general terms to the requirements. The computer finds application in work scheduling, priority organization, processing control, data analysis, pattern detection, quality control, display of information. Its most common use to date has been in the clinical laboratory, in conjunction with multichannel automatic instruments and analysers. The reasons are that the requirement is easily recognizable, the input and output tends to be specific, and the orientation of those involved is toward the application of technology.

Different types of computerized data management techniques are in use in the clinical laboratory, of which the most common involves the recording of data on punch cards which are subsequently processed in a central computer facility, followed by manual distribution of test reports. Other laboratories have used small special purpose computers, which are both flexible in use and low in cost; while still others have tied their requirements into a central computer facility engaged in other hospital information processing functions.

These automated laboratories can provide biochemical and other profiles in single page printed formats, with more information per patient than formerly; in addition, reports may be flagged when values are beyond the normal range, or as an alternative, the position of the specific value may be shown in relation to the normal range. Information is provided rapidly and provision is made for quality control. As Chapman (1968), from the Palo Alto Clinic, remarks: "Automation offers economy, and when used with a computer, permits direct machine-controlled entry of results without human transcription . . . .

"Computerized laboratory information further enhances the speed and cost factors. Small scale computers or data processors, specifically designed for clinical laboratory work, are modestly priced and within reach of small non-research hospitals. These laboratory computers can gather information from either automated or manual sources and in minutes convert complicated mathematics to significant medical data in a variety of ways useful to the pathologist and the physician.

"From a hospital's view point, computerized laboratories offer the additional advantages over manual operation of better billing and statistical information, greater utilization of hard-to-get personnel, interfacing with present or future hospital-wide communications systems, and less need for interruptive enquiries on the status of individual laboratory tests."

While the above is written with respect to clinical laboratory services, the same principles apply to radiographic investigations and to the various forms of bioinstrumental investigation (ECG, EEG, EMG, pulmonary function, etc.); and indeed much experimental and practical work has been done in these and other fields using the computer for data processing, analysis, curve matching, pattern recognition, treatment control, display of information, etc. Except for those few hospitals and clinics involved, where a full hospital information system is in effect, very little has been done to use computer technology as a means of integrating these services into other hospital activities.

With the increasing complexity of investigative facilities, it would seem, however, that, "The profession must evolve a means to provide accurate, minimally expensive analytic services along with the presence of a physician trained to interpret . . . . This is basically a socio-economic problem; the contribution of the computing system is merely to make it possible for large volumes of data to be transferred accurately and quickly, and to offer the hope that meaning may be added to the results of traditional analysis" (Lindberg, 1968).

The recent report to Council (1969) by the Committee on Regional Organization draws attention to the need for computer-mediated programme co-ordination. The remainder of the need in other specialist areas speaks for itself. As diagnosis and treatment become more dependent on medical technology the need to co-ordinate that technology becomes the more pressing. The digital computer offers the tool by which it can be done, but intensive study is still needed by competent specialists before decisions can be made on the progressive steps of implementation.

MEDICAL DIAGNOSIS

The use of a computer as a primary diagnostic device is theoretically possible even in the present state of the art. In fact, to a limited extent it has been employed for this purpose already in certain

restricted fields, using for example the application of Bayesian theory to determine probabilities of occurrence of certain types of congenital heart disease (Warner et al, 1961). Application on a broader scale, however, is still a long way off, and requires a clearer understanding of the nature of the diagnostic process in a manner precise enough to simulate physician behaviour with a computer programme.

It is probable, however, that much can be gained by using the computer as an aid to diagnosis, or as an aid to memory, such that by referencing appropriate data banks and utilizing branching logic one can be presented, in a man-computer dialogue, with significant features of relevant diseases and potential differential diagnoses. Much of the diagnostic process consists of sifting in a semi-intuitive manner the relevant from the irrelevant, and in developing hypotheses from the incomplete data available. The computer, with its ability to store and rapidly recall vast amounts of data, can assist in this process.

It would seem, however, the advantage to be gained by use of a computer for this purpose at this time would scarcely justify the enormous storage requirement and programming complexity that would be required, although there is little doubt that in the foreseeable future computer-aided diagnosis will be a desirable reality.

PATIENT MONITORING

Continuous monitoring of physiological function has become an accepted practice in units specializing in the intensive care of the critically ill. The objectives are to provide a readily available, organized, legible and continuously updated record of the variables measured. Electronic data processing lends itself readily to this task and is being increasingly used for the purpose. Not only can the computer collect, store, and display large quantities of data at a fast rate, but it can also be used for the calculation of derivatory information, and trend information, as well as for the presentation of alarm signals when values exceed predetermined limits, or to control the display of normal values for comparative purposes. Closed-loop computer control is also being currently applied in the experimental management of such conditions as diabetic coma, and there is little doubt that treatment scheduling in intensive care may well become an accepted function of computerized management.

Currently, the major limitation lies not so much with the computer as with the relative inflexibility and inadequacy of the measurement systems employed. Even the successful efforts are relatively primitive, and monitor little more than a few primary variables, such as blood pressure, heart rate, respiratory rate, respiratory volume, and urine flow. Nevertheless, it is clear that application of computer technology to intensive care must be looked upon as an important contribution.

MANAGEMENT OF PHARMACEUTICALS

At the government level, whether provincial or federal, there is a need for a readily accessible information retrieval system pertaining to the properties and attributes of all recognized drugs, antibiotics, and other pharmaceuticals. At the hospital level, the need is equally acute but more operationally oriented, with a need for display of information relating to availability, cost, recommended usefulness, restrictions, mode of employment, dosage, dangers, side-effects, etc., presented in such a manner that the physician can select the appropriate agent with confidence. The mode of display of this information belongs in consideration of a total hospital information system, which will be discussed later, but various forms of display can be made available, as for example high resolution television screen with light pen, or teleprinter output.

At the pharmacy end of the system, still further need for electronic data processing exists. Much of the pharmacist's time is taken up with routine labelling and accounting, inventory control, billing, work scheduling, validity checking, and similar activities. In one U.S. hospital, a computerized system presents punch card orders for medication to the pharmacy in the form of a pre-printed gummed roll, and is alleged to save 40 to 45 per cent of each pharmacist's time in merely typing prescription labels (*Canadian Hospital,* Editorial, 1968).

Much has been accomplished in the last few years, both at government and local levels, toward a satisfactory, workable, and working system for the storage and retrieval of pharmaceutical information, and for the automated or semi-automated management of pharmaceutical prescriptions. The need for implementation at the hospital level, however, is becoming more acute. Although in most cases the need has not yet been met, the role of the computer can probably be justified here not only on terms of improved and more efficient service, but also in terms of overall economy.

SPECIAL CENTRES

The blood bank and the poison control centre are two examples of special units with particular need for electronic data processing. The former has a need in particular for inventory control in a critically time-dependent situation, and for the maintenance of information on possible needs, and for the location of potential donors. In other respects, it can derive benefit from computerized management of a type similar to that found in a pharmacy. The needs of the poison control centre, on the other hand, lie not so much in management, as in storage and retrieval of information. The capacity of the computer to sort large quantities of data with easy cross-reference is of particular value to the poison control centre, which may be called on to furnish urgent advice concerning materials known under a variety of names or comprising a variety of constituents. Theoretically, although the practice is yet some way off, it is possible to utilize the computer as an aid to toxicological diagnosis in a manner similar to that mentioned in connection with diagnosis in other fields.

TREATMENT AND NURSING MANAGEMENT

The application of computer technology to the fields of treatment and nursing management is an evolutionary step towards an intra-hospital information system. With punch card, teletype, or light pen input, and line printer or television output, computer processing can be used to assist the routine chores of treatment scheduling, validity checking, dietary management, chart and record preparation, as well as the previously discussed requisitions for medication, blood, X-ray, laboratory, and special investigations. The effectiveness of such a system, however, depends on the existence of operating and compatible subsidiary systems. The nursing station is, in effect, an interface between various subsystems. Thus, the desired nature of this interface, the usage to which it will be put, and the form of the input-output devices, all have to be considered in relation to the design and development of subsidiary systems, since the nursing station is the focal point of patient management within the hospital. Consequently, careful systems analysis is required before a nursing management system can be designed.

DIETARY MANAGEMENT

Hospital dietary practice is still another area where efficiency can be improved by electronic data processing. Management again is akin in principle to that of the pharmacy, whereby orders are issued by

punch card, teletype, or light pen at the nursing station and received in like manner in the hospital kitchen. In the kitchen itself, depending on the extent of automation, the computer finds use in order scheduling, validity checking, dietary planning and menu formulation, inventory control, accounting, billing and similar activities. Again, however, the development of such a system must be considered in the light of the design of an intra-hospital information system. It does not require to be implemented in totality, but can be permitted to develop in an evolutionary manner to conform with the design and practice of the total system.

INTRA-HOSPITAL INFORMATION SYSTEM

The ultimate aim of electronic data processing in the hospital environment lies in the development of an intra-hospital information system, serving the needs of the patient, the physician, the nurse, the supporting staff, the administration, the scientist, and the educator. Attainment of the system, however, can be recognized as an evolutionary process, with development and extension from system to system until all are integrated in one conjoint body. Barnett (1968) succinctly describes the advantages that accrue with a total system: "To the physician, this means a system which will provide rapid, accurate, and legible communication of reports, better scheduling procedures, and timely and precise implementation of activities ordered for patient care. To the nurse, [it] implies an operation to lighten the clerical load of communication functions, preparing requisitions, and transcribing and charting. To the administration, [it] is a means for using resources more effectively, for gathering the data necessary for appropriate management decisions, and for ensuring that information necessary for the patient billing process is readily available and accurate. To the medical research investigator, [it] offers the potential for a data base of patient-care activities that is not only accurate but also organized and easily retrieved and analysed.

"The major emphasis in the development of an intra-hospital information system has been in the use of a real-time, on-line computer system with multiple input-output terminals located in patient-care units and in all service areas."

One such system is currently being implemented to meet the needs of four hospitals in Carolina. This system is expected to produce two major benefits for the hospitals, namely, reduction by 50 per cent in the time spent on paper work by professional staff,

and improved treatment by way of more efficient staff scheduling and communication. The result is expected to reduce patient hospital stay by one day, which in turn represents a 12.5 per cent increase in bed space in a situation where hospital construction costs run at $30,000 to $45,000 per bed. The system itself is estimated to cost $75,000 (Rankin, 1968).

In the working system, the services provided will include the following:

(a) Doctor's orders and other communications from nursing stations to the hospital's service departments;

(b) Nursing service administrative functions (nurse staffing and scheduling, patient condition reports, nurses' notes, etc.);

(c) Hourly scheduling for all departments (radiology, pathology, operating rooms, physical therapy, nurses' stations, etc.);

(d) Communication of service department test results or diagnoses to the proper nursing station, with recording of information in the appropriate patient record;

(e) Maintenance of medical records in computer storage;

(f) All accounting and financial functions;

(g) Dietary planning and menu formulation;

(h) Daily scheduling of hospital maintenance and housekeeping;

(i) Supply inventory, usage reports, and purchasing procedures.

In practice, an order received from a physician at the nurses' station is entered on a keyboard with identifying information. The data is displayed on a screen with other patient information and subsequently stored in computer memory. A verification copy is produced by an associated printer. The computer compiles care and medication schedules in duplicate on high-speed printers for each nurses' station for each shift. One copy is retained as a record; the other is separated into its component parts and given to individual nurses responsible for various tasks. Schedule changes can be made at the station, stored in the computer, and incorporated into new schedules as they are printed.

Pharmacies and other service departments also receive appropriate schedules, incorporated, as required, into the patient's chart. All entries are validity-checked by the computer to verify contents by patient number, doctor's number, and transaction code. Assignments to be completed are stored in computer memory and interrogated every hour until completed. Appropriate reminders are printed out by the computer.

In the future, display units will be available to doctors at their clinics, enabling them to check on a patient's progress and receive test results directly from the computer. Other phases of the programme will assist in gathering medical history information, and sort post-case histories.

To develop such a system is, however, a vastly complex endeavour. The need, nevertheless, is there, and the advantages obvious. But, as Barnett (1968) states, ". . . [Efforts must be] directed toward the painful, slow evolutionary process of developing and implementing modules or building blocks for individual functions. . . . Stringent reliability requirements and the difficulties attendant when non-technical personnel use a computer system on a round-the-clock basis have been two of the key limiting factors in . . . development. . . . If the experience of other industries is repeated in hospitals, the use of computers in hospitals will not reduce total medical-care costs, but will lead to more effective use of the resources at hand and to improved patient care."

RESEARCH AND EDUCATION IN THE HOSPITAL ENVIRONMENT

The use of computers is already well recognized in biomedical research. Both on-line and off-line systems have been employed, either by way of some available large multipurpose system, or by the direct employment of small special purpose systems. Most common usage has been for data collection, processing, application of statistical techniques to acquired data, pattern recognition, curve matching, etc., and occasionally for control and management of experimental procedures. An established hospital system, however, opens up a wealth of new and readily available material for retrieval under a variety of classifications, which can be easily sorted, and made available for sophisticated analysis.

Perhaps an even greater need exists, however, for ready access to research literature. The hospital computer can be used to meet this

need both directly and indirectly – directly, by the development of a local literature information retrieval system for use within the hospital and associated area, or indirectly by tie-in to one of the large library retrieval services.

Using literature references and/or abstracts and appropriate software, it is not a difficult matter to develop an effective literature retrieval system to serve the needs of a hospital library. Using an appropriate semantic tree or thesaurus structure, such a system can be devised to allow entry by subject matter at different levels of specificity, by author, journal, text, or any selected index. Various national and foreign (particularly USA) organizations have developed large systems of this nature which can be interrogated by phone, mail, etc., or which could, by suitable agreement, be brought on line. An example is the MEDLARS system of the U.S. National Library of Medicine which has information on more than 6,000 different journals in fields related to medicine. Various other systems, both private and public, exist for similar purposes, each tending to specialize in a limited area.

Education, of course, is an outcome of research. Lindberg (1968) echoes one of his colleagues when he points out that the increase in number of medical specialties parallels the increase in the amount of biomedical knowledge, and argues that the formation of medical specialties has been necessitated not so much by what a person can do as by the size of the body of knowledge he can command. Computer techniques offer the first possibility of reversing this trend by making a very large body of knowledge available to each physician. Perhaps, in fact, a physician of a new type will develop, who is not required to memorize vast quantities of facts, figures, and suppositions, but who is trained, after careful interrogation, observation, and description of the patient, to collate and interpret facts and suggestions presented to him by a computer with a factual memory which can far exceed his own.

Even if we are still far from this stage, there is a continuing educational need to be met which can be assisted by the computer. Thus it is of importance to direct our efforts toward development of systems, which, in addition to their primary function, can spontaneously volunteer information to the physician when a clinical situation arises which makes that information appropriate. This can be most usefully achieved in the form of computer-physician dialogue – a technique which, although still in experimental form, shows great promise for this purpose. In conjunction with entering,

for example, orders for medication or treatment, or perhaps in more advanced systems that provide assistance in diagnosis, the computer can insert additional information as an aside, or the physician can specifically interrogate the computer for information and conduct a dialogue with it using branching logic in a conversational mode.

Educational systems of this kind, of course, demand specially created data banks to cater for the particular interests of the educational programmes. The technology to create and operate banks of this kind is already with us, but considerable discussion might well ensue about the content, and priority of implementation. Obviously, implementation would be predicated on the existence and successful operation of a total health information system, but once the latter is established, addition of educational data banks and capacity for computer dialogue is not difficult. Sources of information could be compiled and correlated by appropriate consultant committees and stored as items within the system. To ensure adequate control each item could have an identifying number, a code number identifying the contribution, a code number identifying the basic source, an estimate of reliability by the committee, and a date signifying when the item entered the bank, which would also be used as a reference for review and revision.

While it is not suggested that this type of activity should receive primary consideration in design and development of a hospital computer system, it is believed that its potential development should be borne in mind in the conceptual stages for implementation when the occasion is suitable.

ADMINISTRATIVE NEEDS IN THE HOSPITAL ENVIRONMENT

Many of the needs of the administration have been considered during the earlier examination of the total hospital information system. In fact, it is perhaps emphasizing an undesirable separation if one considers the administrative needs as being distinct from other requirements in a hospital system. At the same time, since the major use of computers outside of research activities has been in administrative procedures, much can be learned from examining administrative systems established for many years.

As in other fields, the major advantage of the computer to the hospital administration lies in its capacity to store and process large quantities of data. Ready access to pertinent data improves

accounting, streamlines billing procedures, increases cost effectiveness and provides more definitive information for planning purposes.

In a fully established hospital information system, billing can be automatically processed, and copies of relevant and necessary records automatically made available to the administrator. He, in turn, by interrogating the system, will be able to obtain such information as he may be privy to. Enlargement of the system to management of personnel records, payroll, tax, insurance, pension and benefit programmes, is already common practice in industry and some hospitals, while extension to take into account inventory management, laundry and linen management, bed control, personnel and maintenance scheduling, is well within technological capacity at this time, and limited only by available resources. In fact, it is probably in the administrative area that direct cost savings might best be demonstrated.

In a discussion of significant factors in an information processing system Baruch (1968) points out that access speed is relatively unimportant to the hospital administration. Except for the limited cases of billing inquiry and benefit availability, there is little reason for high access speed. On the other hand, the batch processing ability of the computer becomes a great asset because of the large volume of accounting, planning, and personnel data that needs to be processed. Similarly the capacity for maintaining record continuity becomes an asset, particularly for those areas of administration that depend on a longitudinal record, such as tax procedures, inventory control, depreciation, amortization, and planning data.

Experience has shown that the use of computers in the hospital environment, aside from research, has tended to begin in the administrative field, particularly in the areas of billing and personnel financial management. The reason for this may lie partly in the fact that the administrative needs are relatively circumscribed, and partly in the fact that advantage can be taken of the knowledge gained in similar forms of data processing in industry. It may be appropriate to continue this process in those centres where computer use for this purpose is already established, while encouraging extension into other administrative areas. From there it would be a relatively short conceptual step, although requiring careful planning, via the semi-professional route of admission and discharge control and record-keeping, to the beginnings of a professionally oriented system embodying the features outlined in this presentation. The cautious would advise this approach, and in fact it is probably most appropriate

for major hospitals which already utilize computer facilities to a greater or less degree.

For those smaller centres which have the need but not the facilities, perhaps a bolder approach is necessary, whereby, after a needs analysis of the hospital or group of hospitals serving the community of concern, a system is designed *in toto* to meet those needs, for phased development over a prescribed period of time, in the light of available resources. To do so would first entail defining the communities of interest and the hospitals serving them, and thereafter establishing priorities of implementation both with respect to the communities and to the computerized services provided. This process is, of course, to some extent already under way in connection with the development of regionalized health care delivery systems, and will be enlarged on during discussion of the model conceptual system considered by the Sub-committee.

SECTION VI

Application of the Computer to Health Care in the Community

In contrast with the hospital environment, much less work has been done in application of computer technology to the health care needs of the community. This, however, does not mean the needs are not there. All too often, in fact, the needs are recognized but not defined. The physician in his office is very much aware of the lack of adequate information on his patient, of the limitations and delays in communication with hospitals, laboratories, treatment and investigation facilities, and public services. The public health practitioner struggles with the implementation of health programmes, cumbersome records, and manually prepared statistics. Social and community service organizations, public and private, duplicate their records and dissipate their efforts amongst a population whose requirements are only partly comprehended. The introduction of medical insurance and care plans, particularly the Ontario Health Services Insurance Plan with its computerized record systems, has brought some clearer measure of community needs, but as yet in a limited fashion. A more comprehensive system must be examined to meet the total needs.

The essence of the community system must lie in development and maintenance of a comprehensive birth to death personal health record, with linkage to information contained in the records of other systems and subsystems including all intra-hospital information systems. This in turn demands a means of unique identification of every individual in the province, and in fact, in the country, as previously discussed. Virtually every individual already has some type of medical record -- birth records, school and university health

records, military and government medical records, occupational health records, medical insurance records (private and public), physician and dental records, and in some cases hospital and Workmen's Compensation records. The technology by which to integrate these into linked records at whatever geographical and organizational level is desirable is already with us. The clerical and administrative effort needed to do so is, however, gigantic, and is further constrained by available resources and the need for preservation of individual privacy. The latter is the subject of a specific section of this report.

The Sub-committee recognizes that the district systems, along with the community aspects of the hospital systems, must be the primary areas of activity of the entire provincial medical network – acting as storage centres for personal medical data, clearing houses for incoming data from diverse sources, and vectors, via record linkage, toward sources of information held by other systems and subsystems.

Many of the techniques of data acquisition and recording discussed in connection with the hospital system with respect to medical history and examination, X-ray, laboratory and other diagnoses and interpretation, are just as applicable in the community system. In fact, the hospital medical record is a subset of the personal medical record, and in the ultimate system it would be either stored with the personal medical record or linked to it in some readily accessible manner. It might be noted in passing that even figures, diagrams, physiological records, and images can be stored on microfilm and retrieved by computer guided search.

Perhaps the prime example of the application of computer technology to community health care lies in the Multiphasic Health Screening programme offered by the Kaiser-Permanente Medical group to some 40,000 adults annually in the San Francisco Bay area (Collen, 1966). Automated multiphasic screening is the concept of utilizing automated and semi-automated electronic and mechanical equipment to perform multiple tests and to determine automatically whether there is sufficient likelihood of the presence of a number of diseases, so as to separate out persons who are likely to have these diseases from those who very likely do not.

The process consists of three parts: a battery of computer directed history and screening tests, a physical examination by an internist (computer recorded), and a group of specialty physician

examinations, including both gynaecological for females and sigmoidoscopy. Computer processing is on-line and is responsible for suggesting supplemental tests and appointments, as advised by pre-programmed rules.

The majority of the data generated is recorded on pre-punch or "mark sense" cards to permit immediate introduction into the data processing system which evaluates the data in the light of various test limits and decision rules and prints out appropriate recommendations.

As an off-line procedure, the computer collects and stores on random access magnetic storage the remaining information as it arrives (e.g. mark sense physician interpretations of ECG, X-ray, retinal photography, laboratory test reports, etc.). When all information is received and stored, the computer produces a printed summary of all test reports and of questions answered in the affirmative. Additional special research procedures are also undertaken.

It must be emphasized that the Sub-committee does not suggest that multiphasic screening programmes of this nature be introduced throughout the province on a community-wide basis, although many of the principles and techniques adopted are worthy of close examination. It is considered that the cost effectiveness of this type of programme over a broad population is not clearly established, although it might become so over time, in which case it could be introduced if deemed desirable and within available resources. The system considered by the Sub-committee is both less and more than that of the Permanente group; less, in that it is not primarily intended to provide massive screening services for the sick and the healthy, and more in that it is designed to improve communications among physicians, patients, service facilities, health scientists, government and other planners and adminsitrators.

With implementation of the system, there will be a need for access via remote terminals for those who have a legitimate right to participate. Those entitled to access at different levels might include private physicians, medical clinics, laboratories, dentists, public health physicians, occupational health physicians, community health planners, etc.

The requirement for record linkage becomes of paramount importance in the design of a community system. It is apparent that

the needs of users will vary immensely. Some will require full access to a limited amount of data, e.g., physicians for the medical histories of their patients; some will require limited access to broad variety of data, e.g., public health planners for planning data; while most at one time or another may require access to data normally in the purview of some other individual or organization, e.g., a physician for the medical history of an emergency patient from another locality, or a government department for planning statistics. It is neither necessary nor reasonable for all information to be retained in a single data storage unit, even if it were technologically feasible. It is much more reasonable for functional units within the system to be responsible for storage of the data of particular interest to them, provided that suitable headers and pointers are incorporated in the various subsystem storage units to indicate where the information is held. The network suggested by the Sub-committee operates on this basis. It remains to be determined however, what the limits of these functional units will be.

As Gabrieli (1968 a) points out, a health care community system is deeply embedded into the complex structure of the community. While some subsystems are readily discernible, e.g., hospitals, medical schools, or county health departments, the actual borders of the subsystems are diffuse. The significant matter is the content of the record and the cost involved in including the record in the system. Without defining the storage location, or the responsible organization, he suggests the following should be included as part of a community record:

1. Perinatal records

   (a) clinical and social aspects of delivery
   (b) complications of delivery
   (c) neonatal data – weight, anomalies
   (d) drug history during pregnancy

2. Notifiable diseases

   (Automatically processed for planning purposes.)

3. School Health record

   (a) periodic physical examinations
   (b) immunization status and scheduling
   (c) illness records

(d) scholastic performance and family situation

4. Screening and routine examinations

    (a) pre-admission school records
    (b) pre-employment records
    (c) pre-marital examinations
    (d) pre-insurance examinations

5. Research surveys

    (a) household interviews
    (b) health examinations
    (c) epidemiologic studies

6. Absenteeism data

    (a) school
    (b) work

7. Military records

    (a) health and assignment records
    (b) veteran's records

8. Occupational health records

    (a) injuries
    (b) diseases

9. Hospital records

    (a) in-patient records
    (b) out-patient records

10. Clinic records

    (a) well-baby clinics
    (b) geriatric clinics
    (c) diabetic clinics
    (d) health welfare centres, etc.

11. Disease registers

    (a) cardiovascular and stroke

(b) crippled children
(c) congenital malformation
(d) cancer, etc.

12. Social security and health insurance data

13. Personal physician records

14. Mortality records.

Although the above is a comprehensive list it is not presented as a recommendation for implementation but for consideration as a guide to establishing the needs of a community system. It might be noted that no dental or optometric information is included, and furthermore that the system might well benefit from linkage with safety organizations, driver's licence registry, environmental health units (including air pollution and water resources), etc., while access to library sources and information data banks is no less significant in the community system than in the hospital system.

The community system, however, must do more than act as an efficient means of storage and retrieval of data. In its established form, supported by other communication facilities, it must provide for more comprehensive and more effective communication amongst its users – the physician, the hospital, the out-patient clinic, the X-ray, laboratory and pharmacy, the public and private health organizations, the administrator, and planner – in a manner similar to that by which the total hospital information system improves communications amongst its users. Eventually, one might even look forward to the provision of computer assisted data analysis and interpretation, computer advised investigation, and computer aided diagnosis, as well as programmes for patient referencing and scheduling, and programmes for physician education and information on diseases, drugs and treatment, all at the community level.

For the implementation of even the most primitive community-wide health record linkage, however, an extensive systems analysis is required for each area where health related documents will be generated or filed, with the objective of defining specific needs and developing compatible recording practices within the community. The initial strategy must be conservative. The medical and associated communities must be convinced that health record linkage and computer storage represent progress in medicine. The cost and technological aspects need to be further explored in a limited

operation, and only after adequate experience and full development of technical capabilities could a larger system be considered for implementation.

It is apparent that implementation of a total system to meet the needs on a province-wide or even region-wide basis is a gigantic undertaking. On the other hand, failure to examine the total requirement and to direct a process of quickened but controlled evolution will lead inevitably to development of a profusion of small systems, designed to meet local needs, perhaps incompatible with one another, and unsuitable for the vital factor of record linkage.

It would seem mandatory to begin the necessary systems analyses now, before developing systems become too firmly established, to define the communities of concern and their needs, to outline the information and processing requirements of various groups and prepare specifications for compatible software and hardware.

The individual, healthy or sick, must be the focus of the total system; and community systems, along with community aspects of hospital, public health, and ancillary services, must be the primary areas of activity of the entire medical network, acting as storage centres for personal medical data, clearing houses for incoming data from diverse sources, and vectors, via record linkage, toward sources of information held by other systems and subsystems.

Insofar as the proposed health information system is concerned it must be recognized that the hospital per se plays the same role as any other participant, individual or corporate, in the delivery of health care in that it acts as both a provider and a user of information. At the same time it must also be recognized that with respect to the varied applications of computer technology the needs of the hospital in terms of an intra-hospital information system are both complex and comprehensive. The two requirements, diverse though they are, are not incompatible, and any proposed computer support system must be designed to meet the needs of both.

SECTION VII

Health Information Needs within Government

We are living in an era when government has to accept an increasing responsibility for the provision of public services. This holds particularly true in the field of health care services. Here the demands have risen so greatly that the total annual cost to the Province is beginning to approach one billion dollars. A programme of such magnitude has necessarily intensified the administrative task and made vital the need for both long range planning and operational research. At the same time two other functions of government service, registration and provision of data, have had to keep pace. Yet another function is the role of negotiant which would emerge during any federal-provincial discussion concerning compatability of provincial systems.

Long range planning, operational research and administration places particularly heavy demands on a data base since it must be broad enough to incorporate in one file (or effectively one file by linkage) all pertinent correlate data elements. Thus the data base must incorporate files of health manpower information (age, specialty, year and place of graduation, place of practice, type of practice, etc.), of physical resource information (type and capacity, age, location, utilization patterns, etc.), of morbidity and mortality information, and of demographic information, to name a few. Inevitably, planning is based to some extent on trends of past data which means that the data base must not only be broad but be deep in spanning as many years as possible. There being no data base of this sophistication in the province it behooves the Province to implement one as soon as possible. This presages the development of

a Health Information System.

The registration function of government insofar as it touches upon health status includes the registration of births, marriages, dissolutions, deaths, certain morbid conditions and health insurance contracts. This function creates files of information all of which should be made linkable and readily accessible. It is a moot point whether the files of certain morbid conditions are created or are augmentations of other file records.

The provincial government has a responsibility to provide statistical material for the information of citizens to assess the health status of the Province, to carry out special studies where the government has the more direct access and more resources to research the data, to provide (by agreement) other provinces with comparative data and to provide (by agreement) WHO comparative information in such areas of interest as infant mortality rates by diagnosis.

A key factor, alluded to several times above, is that of file linkage. There exist a number of files of health or health-related information which cannot be linked because of incompatible formats, codes, data elements accessed, geographical separation and lack of communication. Some agencies and the nature of their files are: Dominion Bureau of Statistics – population decennial and quinquennial censuses and divorce registers; Department of Municipal Affairs – annual assessment and census; Department of Transport – meteorological data (federal), automobile accidents (provincial); Department of Labour and Workmens' Compensation Board – industrial hazards and industrial accidents; Department of Health – laboratory tests, water pollutants, communicable disease reports, psychiatric institutions, and morbidity; Ontario Hospital Services Commission – hospital morbidity, hospital resources, nursing homes, physiotherapy clinics; Health Insurance Registration Board – morbidity of citizens and services provided by practising physicians; Registrar General – births, marriages and deaths; Department of Social and Family Services – social worker activity and nursing homes; Centre of Forensic Services; Ontario Water Resources Commission – pollution levels.

If administrative and planning functions of government are to have adequate resources so that decision may be based on facts wherever possible, then a supporting data base must be created. Further, to ensure capture, organization processing and ready retrieval of information, the data base must be served by a computer

network with adequate storage devices. And further still, the data base must include information from health related files held by other governmental departments, other agencies and so forth. This requirement leads finally to the conclusion that linkage of files is a necessity and must be simplified if costs are to be minimized.

SECTION VIII

Current Developments in Health Systems

This section surveys the current uses of computers in medicine, abroad and in Canada. In general, these uses can be divided by function into a number of different categories, each of which will be discussed in sequence. These are:

- communication between medical centres
- communication within a hospital complex (a hospital information system)
- teaching and research applications
- diagnostic and therapeutic applications
- accounting, organizing and statistical applications.

Note that in this section only the present state of the art is discussed; all equipment and techniques described here already exist and are in operation.

COMMUNICATION BETWEEN MEDICAL CENTRES

Many business firms are using commercial communication networks for transmitting data, both analogue and digital, between centres, and no new or special equipment would be required to transmit medical data. On the TWX and TELEX teleprinter services, for example, subscribers can dial one another (using a conventional

telephone dial), and data can be transmitted either by human operators on teletypewriters or directly from machine to machine. Many computer companies in Canada have time-sharing systems on which a remote customer has access to the computer through a teleprinter or telephone dialling network. Many firms, for example Ontario Hydro, use a teleprinter network for accounting and billing. There is no distance limitation to these systems, but the maximum data rate is usually about 100 words per minute.

Data can also be sent at much higher speeds. Although the cost per unit information may be reduced, the capital outlay for equipment is much greater. For example, IBM is in the process of providing high-speed communication links amongst its 23 Canadian centres, stretching from Vancouver to St. John. The installation of a similar network of medical computers throughout Ontario is well within the limits of modern technology.

Analogue data, such as electrocardiogram traces, may be transmitted through the telephone network by using acoustic couplers, devices which convert electrical signals to audible sounds. In particular, Caceres (1967) uses these devices to transmit electrocardiograms from a physician's office into a computer for analysis and interpretation. Caceres' system is being implemented at Queen's University, Kingston, and this service will soon be available for physicians in Ontario.

COMMUNICATION WITHIN THE HOSPITAL

A number of prototype hospital information facilities are in operation, notably in the U.S.A., Britain and Sweden. The best known are large scale multi-hospital information systems (which implies communication between hospitals as well as within the hospital); namely the Medidata System based on Burroughs equipment, the Medinet System based on G.E. equipment, the Medical Information Systems Program (MISP) based on IBM equipment, and the Lockheed Missile and Space Company's Hospital Information System. Each of these four systems is still being tested on a limited scale before being fully implemented (Singer, 1969; Biomed, 1969). For example, the Medinet System is currently being tested in a number of hospitals throughout New England and is in full use in one hospital in New York.

In addition to the multi-hospital systems mentioned above, a number of individual hospitals have developed and installed single

hospital information systems (Singer, 1969). The largest of these in operation today is at the Downstate Medical Centre in New York, which, in a 350 bed hospital, has more than 100 terminals on-line to a computer. The hospital estimates that about 85 per cent of its administrative activities are based on the computer system. The Texas Institute for Rehabilitation and Research is implementing a computer system, involving about 20 terminals and a large scale computer shared with the University Medical School. One of the earliest systems was installed at the Manchester Memorial Hospital in Connecticut in 1964 to handle patient accounting, statistical data and payroll accounting. A somewhat similar system was installed in Birmingham, England, in 1966 (McLachlan & Shegog, 1968); another system was built by Standard Radio & Telefon AB (a subsidiary of ITT) at the Karolinska Institute in Sweden (Marcus, 1968).

The basis of all of these systems is a centralized computer which is connected to communication terminals at the admissions desk, at every nursing station, in the clinical laboratories and in areas such as radiology, pharmacy and the diet kitchen. The system allows the integration in one central computer file of all laboratory, administrative, clinical and other information about any particular patient. A current patient record can be called for at any station; orders for medication can be entered, automatically checked by the computer and routed to the appropriate department. Patient schedules are printed for each shift at the nursing station, and reminders are given when it is time for medication, etc.

Systems produced by various manufacturers differ principally in their means of data presentation. For example, the Ahearst, Massachusetts System uses conventional teleprinters at the various stations, whereas the Karolinska system uses electronic display units with a sophisticated keyboard entry. Functions performed by these systems are all generally similar.

The principal function of such a system is to store large amounts of text in a form which can be rapidly searched, retrieved and reproduced. At least five systems are commercially available which would be suitable for medical data storage.

The IBM Datacell stores computer data only in machine readable form. Each Datacell can contain up to 400 million characters (about 250,000 pages of text), and the average time to find a record is about ½ second.

A Foto-Mem random access mass memory has, in a desk-sized cabinet, a storage capacity equivalent to about 1½ million pages of text, and access times averaging 30 milliseconds. Both computer readable data and pictorial data (X-rays, etc.) can be recorded; thus about 500,000 patient records could be stored and any one found and retrieved in only a few seconds.

The Sanders-Diebold automatic microimage retrieval system uses photographic microforms, which can contain digital and pictorial data. The largest size has a capacity of over six million pages of text, and the average retrieval time is eight seconds.

The Ampex Videofile uses television videotape recorders to store text; it is not computer compatible. About 1,500 records are immediately accessible, being stored on-line; other records are available on master files, and can be located and transferred to the on-line file in two or three minutes. This system is used extensively by Southern Pacific Railways to store waybills and by the American National Insurance Company for insurance policies.

The Recordak Miracode system uses film magazines, each of which is initially selected by hand, but is then scanned at high speed to find a requested record. The record can be in machine readable form or can be generated by a computer output. Up to a million pages of text can be stored and a desired record found in about 15 seconds. This system allows searching only of the magazine which is on-line; the operator must know beforehand which magazine should be mounted.

TEACHING AND RESEARCH

The ability of the computer to store programmed text gives it a tremendous potential in teaching and research applications. In particular, many schools are actively engaged in computer aided instruction. In the simplest form, the computer asks a series of questions to which the student replies; the sequence of questions is modified by the student's responses. Many instructional programmes of this type have been developed by IBM and RCA.

The Ryerson Institute of Technology, University of Toronto, O.I.S.E. and University of Waterloo are actively experimenting with, and using, computer aided instruction, but not all specifically in the medical field.

In a more sophisticated system designed for medical training, the computer simulates the patient; the student asks questions and tries to form a diagnosis from the computer responses. A special purpose simulator (SIM-1) has been developed at the University of Southern California School of Medicine for training anesthesiologists (Clark, et al 1968). A computer-controlled mannikin simulates human reactions to anesthetics and allows the student to study critical situations which might prove fatal for a patient.

Many libraries throughout the world are using computers for indexing, abstracting, retrieving and controlling distribution of books and publications. For example, the INDEX MEDICUS, a computer-generated index of medical and paramedical journals, is issued monthly by the National Library of Medicine in Bethesda, Maryland. The MEDLARS service will search an index of medical articles for titles containing certain keywords or subjects. The National Science Library in Ottawa provides a similar service for the life sciences and chemical abstracts. The library of the University of Guelph generates daily lists of all books on loan, including the name of the book, the name of the borrower, date of loan, etc. This same library also provides monthly lists of all available publications, journals, etc. by subject.

By using the computer for data analysis, the research worker is able to use much more sophisticated statistical techniques than before, and to handle much larger volumes of data. These and other scientific uses of computers are well known and need no further comment here.

DIAGNOSTIC AND THERAPEUTIC APPLICATIONS OF COMPUTERS

Computers are used on-line in the monitoring of patients during operations and in intensive care units; the vital signs are read by the computer, are processed and recorded, and if they become abnormal, appropriate warning is given to allow for corrective action (Beaumont, 1969). Variables can be displayed in alphanumeric or graphical form at a number of monitoring locations for the convenience of the attending staff. Experimental closed-loop systems are under investigation.

Certain laboratory systems, in particular equipment for determining and analysing blood samples, are frequently attached to computers to facilitate calibrating and logging the data. Medical Data

Sciences, in Toronto, is installing a computerized blood analysis system which will greatly improve the speed and accuracy of these laboratory tests. A Quebec-based laboratory, Laboratoire d'Expertises, uses the TWX teleprinter service to link its laboratories to some 45 clinics from St. John's to Sarnia. The specimens must still be collected from the hospitals and clinics by road or air transport, but the results are reported back to the physicians the same day by phone or TWX. Such a system could easily be integrated into a hospital information system, automatically appending the results of the tests to the computerized patient record. St. Paul's Hospital in Vancouver also has a successful automated blood analysis laboratory.

At least four major groups have independently developed sophisticated programmes for analysing electrocardiograms and diagnosing abnormalities. These are headed by Drs. Pordy and Bonner of IBM, Dr. Ralph Smith of the Mayo Clinic (IBM 1968), Dr. Caceres, formerly U.S. Department of Health, Education and Welfare, and Dr. Pipberger, Veterans Administration Hospital, Washington, D.C. Dr. Caceres' system (Caceres, et al, 1967) is particularly noteworthy. An ECG can be transmitted from a doctor's office into the Centre by telephone, using acoustic couplers. The analysis can be made immediately, and the results returned by phone or teleprinter. In one experiment, an ECG was successfully transmitted from France to Washington for analysis, and the diagnosis was returned to France within a few minutes. As mentioned before, a group at Queen's University (Milliken & Wartak, 1969) is modifying Caceres' system, and this service will shortly be available to users in Canada. Dr. Manning's group in London, Ontario, has implemented the Mayo Clinic ECG analysis programme and is using it within their hospital.

There is considerable interest in computerized systems for screening large populations for a wide variety of abnormalities. The most publicized system is the Kaiser Permanente Plan at Oakland, California, (Collen 1966), which is processing some 4,000 patients per month. Each patient moves through 20 stations, receiving a battery of 13 tests, and filling out two questionnaires. While tests are underway, data are processed to determine whether additional tests or re-tests are necessary. The physician and the patient then review the test data together. A similar system was developed and used experimentally at Rotherham, England. At an average rate of one patient per minute, this latter system checked for ten chronic non-communicable diseases, including tests for heart disease and cancer, and checking urinalysis, blood analysis and mental health.

The health profile produced by this system was mailed to the patient's family physician. There are at least four similar independent screening systems in the U.S.

In a somewhat similar application, the computer can be used to assist the physician in making a differential diagnosis. He enters symptoms and the results of tests; the computer responds with a list giving the probabilities of these symptoms relating to specific diseases, and suggests further tests to refine the diagnosis. Programmes of this type have been devised by Warner et al (1964) and by Boyle et al (1965).

ACCOUNTING, ORGANIZING AND STATISTICAL APPLICATIONS

The computer is used by many business firms for billing, salary payments, for stock control and for generating reports and statistical summaries. A system for hospital usage could also include admissions and discharges, scheduling operations and lectures, arranging shift schedules. None of these additional requirements are particularly difficult or novel. In fact, both OHSC and OMSID are using programmes which perform some of these functions.

SECTION IX

Legal and Related Problems of a Health Information System

The problems to be discussed in this section are concerned with the handling of health information. They are not new problems. But when a computer is involved in the information handling and processing, the relative importance of the problems may change and ways of dealing with them may have to be modified.

These problems will be divided into three broad classes which overlap considerably; privacy – protection for the individual; reliability – maintenance of accuracy of the information; security – protection against loss and destruction.

PRIVACY

Two of the main sources of health information on the individual are the physician's files and hospital medical records. In the first case the information is given in confidence within a relationship recognized in common law. In the second case information may not be released except to certain specified persons under Regulation 523 of the Ontario Public Hospitals Act (OHSC, 1969 b). Thus the individual's right to privacy with regard to health information is covered under the law.

However, there is bound to be a great deal of additional biographical information on an individual's file which would be treated differently. There has been great concern recently about data banks and the possibility of invasion of privacy simply by having access to a "life history." Each item of information may appear

innocuous by itself but not when many such items are brought together. This concern is evident in the Ontario Law Reform Commission's Report on the Protection of Privacy in Ontario. Under the circumstances it does not seem appropriate to make a distinction between medical and other information.

Protection of the privacy of the individual is only a problem if the individual is identified. Much of the time, information will be needed for statistical use. If the individual is not identifiable, access should be made relatively simple and easy. It should be noted however that the deletion of the name on a file may not be sufficient protection. There could be on the record unusual medical, occupational or other information which would be quite enough to identify the individual.

The problem is real when information on an individual is to be disclosed. The first need is the definition of rules for disclosure. In Section 41 of Regulation 523 (OHSC 1969 b), the persons who have right of access to hospital records include a person with a process (that is, a court order), an inspector of the Department of Health or OHSC, a coroner, elected members of the Council of the College of Physicians and Surgeons of Ontario. Other persons who *may* be allowed access with the approval of the hospital board include the attending physician, the patient or his representative, a member of the medical staff for teaching or approved research purposes, the Director of the Division of Medical Statistics.

These regulations form a starting point but are far from complete when one considers them in terms of a computer based health information system. Let us consider the different demands for information in terms of the use to which it will be put. In the following discussion it is important to distinguish between the provision of specific information and giving free access to files. In the first case it is easy to maintain control over the items of information provided and the qualifications of the recipient. In the second control is very difficult and indirect.

Health Care: When the information is to be used for the direct benefit of the individual, medical and hospital personnel should be able to have access to the file although not necessarily all of it. Two major problems are identification of the person requesting information and selection of the information to which he may have access. Identification is even more of a problem when remote terminals are used, although computer technology has provided some solutions for

identification (Ware, 1967) using special cards, code numbers and so on.

The selection of information to be disclosed is more difficult. Although paramedical personnel might need to know some items, there is no necessity to open the whole file to them. However, general rules would be hard to define and difficult to enforce.

Whatever rules are made there should be some means of bypassing them in the case of an emergency.

If there is no urgency about access to files then the need for devising automatic identification procedures does not arise and current methods for personal identification could be used.

Health Insurance: The health insurance agencies need information on individuals in order to do their accounting and administrative work. In general, acquisition of this information does not require access to a complete file. Information could be made available by routine procedures with the formal consent of the patient where required. It would seem reasonable that these agencies maintain the same standards of disclosure as are expected of the health information system.

Other agencies: Medical information might be provided to other agencies such as the Registrar of Births and Deaths or Workmen's Compensation Board. Questions regarding disclosure must be covered under the regulations governing these other agencies.

Private agencies: Undoubtedly private agencies will be interested in obtaining access to health information relevant to their purposes. If such information were needed on a regular and routine basis the right of access of such agencies to health information should be covered by legislation. In the absence of legislation requests could be handled by a Committee to be described below.

Government administration and planning: In most cases the information required would be statistical and presents no problem with respect to maintenance of privacy. Access to individual files could however be necessary, and authority for such access should be properly defined and carefully restricted.

Research: Much of the information used in research will be statistical but occasionally there might be a need to identify an individual. Two

examples can be given. In epidemiological research there might be a need to identify the individual in order to obtain further information or to find references to other files. This might or might not require an actual approach to the individual. Genetics research would require tracing of relatives which could not be done without identification of the individual. It is most important that the protection of individual privacy does not unnecessarily impede properly authorized research. The authorization of access by research workers to individual files could be controlled by a Committee to be described below.

System maintenance: For obvious reasons, systems personnel may have to have access to individual files. Such personnel could easily obtain information if they wished because of their special skills. Consequently computer personnel working with an anonymous information system should be licensed.

Some of the basic points covering the safeguarding of individual privacy have been discussed by Cheng (1968) and others. The basic safeguards seem to be:

(a) publicly known rules and standards of disclosure;

(b) the individual's right of access to verify or modify his own file;

(c) a record of access to files for other than statistical purposes.

The word "modify" in (b) above might seem too liberal a procedure because its literal interpretation would permit the individual to change his file and insert grossly erroneous information. As justification, the following argument is presented: As soon as the information on a person becomes publicly available, albeit to a very restricted public, the individual should have the right to verify the accuracy of the information and delete information that he does not wish to appear on the file. Verification implies the correction of errors, and correction in turn implies that there must be some way of validating the information independently of the individual involved. Such validation would be impracticable and very expensive. People who wish to take improper advantage of this possibility would be few. However, to protect both the patient and the integrity of the information, there are two simple devices. First, a physician should be present when an individual obtains access to his file, and this physician could and should advise the individual as to the consequences of inclusion, deletion or modification of information on the file. Second, on the advice of some qualified committee, files

containing grossly misleading information should be flagged for special attention in order to protect those who might make decisions based on the content of those files.

The foregoing is in keeping with the philosophy that maintenance of his own health is primarily the responsibility of the individual.

These safeguards should be built into the information system. In addition there is a need for legislation to define more explicitly than do current regulations the right of access of appropriate medical and inspecting personnel, and the need for access of others.

In particular there is a need for a Committee to handle special requests for information not covered by legislation, and to handle complaints pertaining to rights of privacy. The Committee would authorize access to files but members of the Committee should not have access to any files while serving on the Committee. There should be right of appeal in cases where the Committee has denied access to the files to an applicant.

There may be a need for legislation to protect those who in good faith provide information to the system, which subsequently can be shown to have caused harm.

RELIABILITY

The presence of errors in health information raises special problems because of harm to the individual and therefore the possible liability of the system and its personnel. It is impossible to protect the system from input errors even with routine editing and validating.

The sources of internal error are hardware and software, the latter being the more probable. Once errors have occurred the source is less relevant than the cure. The problem is then to find the errors, correct them, and in general keep them to a minimum. The solution is to have a continuing audit. The most direct and most expensive way is to check the record with the individual. This may need to be done occasionally. However, by checking a sample of active files against the records from which they were derived a lot of errors can be picked up. An adequate verification system will be expensive but the need for reliable information will more than justify the cost.

PROTECTION

Information is valuable and should be protected. There are the usual natural hazards like fire and flood but in addition data on magnetic tape or disc can deteriorate with time and also could be destroyed in seconds by hardware or software fault.

Careful programming can minimize the chance of the last hazard but it cannot be dismissed. The only solution is the maintenance of triplicate records of the information of sufficiently recent origins that updating is easy. In general this is a matter of system design and the specific choice will vary with the requirement.

The cost of maintaining triplicate files of health information is reasonable and the value of the information is such that these costs should be regarded as an insurance premium. It would be impossible to assess this value but as a lower bound one can consider cost of replacement. With many million bytes of information, replacement costs would be in the millions of dollars.

This raises some interesting questions about what information must be preserved and for how long. Under current regulations some hospital records must never be discarded while others may be destroyed after varying periods of time (OHSC, 1969 b). These regulations will have to be re-examined to define what information will be kept in what form and for how long. New legislation will be required to cover maintenance of all medical records in the light of modern data processing techniques.

SECTION X

Design of a Health Information System

The proposed Health Information System differs from other information systems because of the vast amount of heterogenous information that has to be captured, stored and retrieved over at least the life time of persons. The magnitude of the problem is illustrated by the size of the population of Ontario which is in excess of seven million at present and is predicted to reach ten million within the next fifteen years. If hospital case summaries alone are considered it is estimated that for the 6,000 daily hospital discharges there could be about 20,000,000 characters of information generated each day for data processing. Thus, the problem is primarily one of complex data storage and not of manipulation. The information generated will exceed the capacity for readily accessible data storage of any proposed computer system within the province (e.g., Joint Ad Hoc, 1969). It is emphasized that the point at issue does not arise because of the need for new or more information but because of the need for convenient and rapid access to information currently stored by traditional methods.

The exact specifications of the proposed system will depend on a clear definition of the functional objectives. All too many people hold the naive belief that if enough information is fed into a computer, various hitherto unexpected solutions will be found by the machine. This view must be discounted. It is necessary to determine the source, form, format, accuracy, precision and cost of the data needed to support optimal health care. The Report of the Committee on Health Statistics has provided a framework of reference with respect to data required for epidemiological and

health care planning purposes. One of the major difficulties that remains is to define the data physicians need in making medical decisions and to discover how physicians use these data. "Technology probably does not exist for a hospital information system in its entirety. . . . The present methods of physician procedure, nursing procedure, record-keeping, and information handling will require considerable reworking if the most is to be made of newly developing instrumentation and technology." (Brown and Dickson, 1969.) A major feature of the system will be to unite the speed and memory of the computer to the judgment, pattern recognition abilities, and personal qualities of the physician.

With the scope of the problem defined, the premises which must be considered in the design of the system can be delineated as follows:

PREMISES

1. The proposed Health Information System differs from other information systems because of the vast amount of heterogenous information that has to be captured, stored and retrieved over at least the life time of persons.

2. The exact specifications of the proposed System will depend on a clear definition of the functional objectives. It is necessary to determine the source, form, format, accuracy, precision and cost of the data needed to support optimal health care.

3. The basic information unit in the System will be the individual person.

4. The assignment of a personal number unique to the individual is essential to facilitate record linkage at minimal cost and to retrieve information about patients with minimal error.

5. Original source information should be captured, recorded and organized into an accessible form as close to the time and place of its generation as possible.

6. The individual will have access to and exert jurisdiction over the content of any portion of his personal medical record within the System in which he can be identified by name or number.

7. It is desirable to have all providers of health care as voluntary

participants in the Health Information System.

8. The System will have the capability to link diverse data files from various sources.

9. Only authorized personnel may interrogate the System. Very special care must be exerted in making available personally identifiable data, e.g., for epidemiological research.

10. The System will be compatible with the proposed regionalization of health services.

11. The System will support the needs and resources of the health sciences centres.

12. The System will have a marked impact on teaching, research and planning, but the form and extent of its use for this purpose has yet to be defined.

SYSTEM DESIGN

It must be recognized at the outset that a health information system is concerned with the management of information for many purposes. Not only must it serve the needs of planning and epidemiology but it must also encompass important information areas such as those related to patient management, education, and research. The system is envisaged as functioning at three levels, central, regional and district, with the overall co-ordination of a Linkage Control Centre (LCC)*. Basic information captured from the person at a health facility will be organized and stored in an accessible form for machine or manual processing. Successive summaries of reports from this and other linkable sources will be assembled and stored in cumulative Personal Data Files (PDF) at the district level. Deliberate selection and differential sampling will be applied to these and other files to facilitate the flow of information to the regional level for prospective data collection, storage, processing, and distribution. Flow can proceed in any direction and the system can be accessed at any level. With equal facility it can meet the needs of a practising physician or a governmental agency.

* The designation Linkage Control Bureau of Ontario, first proposed, was dropped after due consideration.

CENTRAL ORGANIZATION AND FUNCTION

By its very nature an information system must embrace all aspects of the organization in which it exists. Numerous disastrous experiences in government and in private organizations attest to the fact that where information systems have been created to function at levels of authority other than the highest, chaos and confusion will inevitably ensue. (Lindberg, 1968; Diebold, 1969; etc.) In consequence, it is mandatory that final reporting and ultimate responsibility must be to the highest level of line authority within the organization. At the same time, to provide a balance of authority within the proposed system which will not merely reflect the interests and needs of government, it is desirable to provide within the organization a system whereby responsibility for personnel and administrative procedures is held along traditional civil service lines whereas functional authority is held by a separate body which can reflect the interests of all concerned and develop policy accordingly.

Authority for co-ordination of the System and development of policy should therefore be vested in a small executive body, the Central Secretariat. The Secretariat will be responsible for co-ordinating the activities and operation of the System, determining the requirements for compatibility, standardization, and performance, and implementing administrative decisions pertaining to computer services. Normal administrative procedures within the System will remain the responsibility of the Department. Another function of the central authority will be to co-ordinate and present data compiled at the regional level from PDF's and other sources either on demand or as part of a prospective data collection.

The Central Secretariat will be assisted by an Advisory Council, made up of representatives appointed from various participating agencies such as a Provincial Health Statistics Agency, Regional Health Authorities, OHSC, OMSID, HIRB, Registrar General, other governmental departments, universities, the Ontario Medical Association, and representatives of the general public.

Analogous bodies responsible for administration and for providing advice on the interests of participants will be created at Regional level (and if need be, at District level), but their detailed structure cannot be delineated until more information is available concerning function and role of regional government.

An illustration of the manner in which the System organization

might fit within the existing Departmental and proposed regional organization is shown in Appendix E. It is emphasized that this Chart is illustrative only.

LINKAGE CONTROL CENTRE

The primary function of the LCC is to interlink the regions with the Department of Health and external agencies such as OHSC, and governmental departments with health related files. In consequence it facilitates transfer of information and Personal Data Files between districts, submission of statistical information from regions to the Department, or exchange of information between departments and other agencies.

The tool to effect LCC function will be a computer mediated index in which will be recorded in a randomly accessible form, the full name, birth date, sex and a unique number such as SIN or Birth Number for each provincial resident. One data cell has sufficient capacity for this purpose.

REGIONAL CENTRE

Inherent in the structure and function of the Regional Centre lies the requirement to mediate between the central and district levels. It is apparent that the role of a region in the delivery of health care has not yet been clearly defined. Until this role is defined, it is difficult for the Sub-committee to delineate the pertinent features of the regional function. Nevertheless, certain broad concepts can be propounded subject to adjustment in the light of developments of regional health care systems.

Of necessity a dichotomous responsibility will exist in that the Regional Centre will be administratively responsible to the regional health council but operationally responsible to the Provincial Secretariat of the Health Information System. The extent to which a Regional Centre is responsible for its own administration and that of District Centres within the region will be related to the powers and activities of the regional health council.

Within foreseeable limits, the basic function of the Regional Centre in the Health Information System is to meet the information needs of the regional health council and to distribute information to and from central and district levels. In addition there will be certain ancillary functions:

1. **Data Switching:** e.g., transfer of a PDF from one district to another where one of the districts may be outside the region.

2. **Collection, Assembling, Processing** and **Reporting** pertinent information to Central, to District Health Facilities and Council, and to Regional Health Facilities and Council.

   Files will contain information such as physical resources, manpower, epidemiological information, and public health programmes.

3. **Support** of Regional Laboratories as required.

4. **Support** of Health Resource Libraries as required.

5. **Support** of Educational Programmes (health sciences centres and community).

6. **Support** of research for health sciences centres and other agencies as required.

7. **Development** and maintenance of information resource banks (pharmacology, physiological ranges and norms, etc.).

8. **Support** of special services (blood bank, poison control centre, etc.).

DISTRICT CENTRE

The primary function of the District Centre is to maintain for each person resident within the District, a Personal Data File of health and health-related information in readily accessible form. For most, if not all districts, "readily accessible" implies a computer serviced data cell storage device (ref: Appendix A). The individual PDF will comprise approximately 200 characters of vital information (name, birthdate, SIN, health insurance number, etc.), followed by units of about 40 characters per illness, treatment, or preventive episode incorporating pointers to the original data. Pending commercial implementation of such devices as high density data transmissions and molecular storage of data through light interference principles, the first instance (access time and queuing) dictates holding the PDF at district level and the second instance (data volume) limits active data holdings to five years with transfer of "inactive" data to tape (ref. Appendix A).

Access may be made to a PDF from above and from below. Each access to each PDF must be logged wherever the individual can be identified. Excepting LCC transfer of a PDF from one district to another, access originating from above district level will normally be for statistical purposes. At whatever level data collection has been implemented, it is envisaged that sampling or selection, together with coding and classification, will take place at District Centres. Collation will be effected at Regional Centres and at LCC.

Access to PDF's from below will be made by a physician or his personally authorized deputy. Either must identify himself (e.g., code number, card, fingerprint, or voice print). Updating of the PDF may be effected by any duly authorized person (public health nurse, biochemist, etc.). Whenever service involves a fee chargeable to HIRB agencies, the PDF update will be combined, for example, with the bill, the provision of data required by HIRB and notification, where applicable, of communicable disease.

While this billing procedure should expedite matters for the practising physician, the District Centre must offer greater service in the interests of encouraging physician participation in the system and of facilitating quality health care. Another major function therefore is the provision of patient-file services coupled with such features as self history taking by patients, ECG analysis, and so forth. Access to a given physician's set of patient files must be restricted to that physician or his personally authorized deputy. As with PDF's each access to a patient file should be logged.

PERSONNEL

It was hoped originally that personnel needs for the Health Information System could be outlined. However a much more detailed definition of the system is needed before useful figures could be worked out. There are two points that can be made now. First, there is no doubt that the demand for computer personnel for the System will strain the manpower resources of the Province to the limit. Second, it will be difficult to find and keep the systems analysts and other senior professionals who will form the nucleus of the System. Without personnel of proper quality and in proper quantity, the system will fail. Consequently personnel needs should be regarded as a priority item in planning.

SECTION XI

Impact of a Health Information System on Education and Research

The existence of the Health Information System described in this report would significantly affect both education and research in the province. However, by the very nature of these areas, it is not possible to describe in detail all of the various ways in which they would be affected, but some of the possibilities are relatively easy to predict.

If, for example, the data described were readily available, the medical records of patients in the province who had contracted a particular disease in a given time interval could be located and assembled. The ability to collect this information would greatly facilitate both teaching and research into the nature of the disease and its treatment. Currently, only by word of mouth does a medical educator know of the existance of cases which might be of interest to his students. The ability to determine where patients suffering from a particular rare disease entity are located could prove most valuable. In a similar fashion, medical research into the prevention, nature, treatment and consequences of a particular disease is often hampered by the dearth of information concerning current and past cases; the ability to collect this information would provide a broader and firmer foundation upon which to base the investigation.

Statistical investigations concerning correlations among a variety of factors, which are now very difficult or impossible to carry out, would be facilitated. As well, the data being entered into the system could be monitored from an epidemiological standpoint, which would aid in the early detection of any change in the incidence of

particular diseases. Which investigations are carried out, and which diseases are monitored depends both upon the cost of performing the function and the benefits derived from performing the function. The existence of the requisite data in an efficient Health Information System would substantially lower the additional cost of performing this type of operation.

Another area in which the system would aid in teaching and research is in the maintenance of an index of pertinent programming systems -- either software, or hardware, or both. This would enable an investigator interested, for example, in the automatic analysis of photomicrographs of large molecules to determine the location of existing suitable systems in order that he might either use or copy one, rather than forcing him to develop his own. Such an investigator would probably already be aware of the work of other people working in the same area, but research in quite different fields often leads to a need for very similar computing systems. For example, the computer system required to analyse physics bubble chamber photographs is similar to that required in the photomicrograph example mentioned above.

The Health Information System could be useful in the same way to educators interested in a variety of programmes that are useful for teaching purposes. These would include general purpose biostatistical programmes, other special scientific programmes, computer simulations of various physiological or other functions, computer-aided instruction systems and so on.

The System could also serve as an "information resources bank" in the health field. In many areas the ability quickly to access current information would be valuable to the educator, student, researcher and clinician. The items in such a resources bank would include a pharmacopoeia, physiological and biological norms and ranges including regional variations, poison control information, environmental parameters, a clinical index of prognostic probability, and so on. It is not unreasonable to suspect that the ability to access such information quickly and conveniently, say, through a local terminal, would change the manner in which the clinician, educator and student performed their respective tasks.

The System should also prove useful to administrators in carrying out the functions of institutional research. Currently it is difficult to obtain answers to questions like: What resources are available? Where are they located? What is the level of need? How is the need

distributed geographically? How has it been changing with time? The resources and needs in question could concern areas as diverse as hospital beds, medical personnel, or computing power. The Health Information System should facilitate the acquisition of information vital to co-ordinated planning. The information that would be collected by the System could be used in the development and testing of computer oriented models of health care delivery systems, facilities and resources.

Each aspect of collecting information, of storing it, of manipulating and retrieving it, has an attendant cost. The benefits to be derived from performing such a function, as related to these costs, determine whether or not such a function should be carried out. The Health Information System would, by lowering information handling costs, make feasible studies which would otherwise be prohibitively expensive, thus making more readily available to the Province the benefits of such programmes.

Seldom, if ever, are computing systems used primarily in the manner in which their designers intended, particularly in the areas of education and research. Old procedures are put to new uses. New ideas demand modification to old systems to satisfy new needs. It is thus impossible to predict with any accuracy the manner in which the Health Information System would be used in these areas, except to predict that it would indeed be used, and probably not in the manner that one would expect.

SECTION XII

Planning and Implementation of a Health Information System

The next step in the development of the concepts and ideas in this report requires the full time effort of a small group of people. The detailed analysis of personnel, software and hardware requirements for the first phases of implementation cannot be handled by a committee which meets only occasionally.

This group will be called the Planning Group and should comprise five people whose joint skills and experience must cover the following areas: the delivery of health care, systems analysis and information processing, and economic analysis. For example the Planning Group might consist of a practising physician, a systems analyst, an electrical engineer, a physician with experience of information systems and an economist. The emphasis is intended to be on the skills that need to be represented rather than professional affiliations. It is assumed that those whose specialty is not in the computer science area are nevertheless familiar with and oriented towards computer applications.

The Planning Group will be responsible to the Deputy Minister of Health. The members of the Group would be non-voting members of the Sub-committee on the Role of Computers in the Health Field. During the planning stages the Sub-committee would continue to report to the Ontario Council of Health and could act as advisory body to the Deputy Minister through the Council.

The duties of the Planning Group will include the investigation of hardware, software and personnel needs; consideration of methods and costs of implementing the system in its first phases both at

district and regional level; the determination of the needs of the users both at district and regional levels; and the provision of advice on the organizational structure appropriate to the Health Information System. The Planning Group should then be in a position to make recommendations about implementation presumably in the form of a phased development based where necessary on pilot projects.

The Planning Group will require appropriate systems analysts, programming, technical and clerical support. In addition it will need to employ consultants as it sees fit to help in its investigations and analyses.

As the System evolves, a Central Secretariat will be required to supervise the overall running of the System. It is probable that when the planning phase is over, the members of the Planning Group may become part of this Secretariat. Therefore, initially, the choice of these members should be made with this ultimate position in mind.

While the Sub-committee recommends that the orderly development of the total Health Information System be the responsibility of the Planning Group, it would emphasize the need for the initial development of a pilot project. This project would be centered on a district or smaller geographical area in which is located a health sciences centre and should encompass the concurrent creation of personal data files of residents of the area along with linkage to basic data files at central level. Because of the magnitude of the task, the Sub-committee considers that the initial pilot project must be of district size rather than regional, and that development of other districts within the region containing that health sciences centre must proceed in an evolutionary manner, pari passu with the development of regional facilities and before extension to other regions.

SECTION XIII

Conclusions

In addition to the Recommendations there are four observations that the Sub-committee would like to emphasize:

First, all the recommendations in this Report and the proposed medical computer system are possible with the existing state of the computer art. However, the frontiers of the field are continually advancing; by the time any of these recommendations are implemented, new and improved devices and techniques may be available. The planning of such a system must always keep up with the new advances.

Second, the hospital information systems and communication networks herein described seem to have evolved around the needs of each hospital or institution. One of the most basic premises of this Sub-committee is that our proposed computer system must be based on the needs of the individual and of the community.

Third, some computerized systems that have been tried have resulted in expensive failures. These failures had two principal causes: incautious planning and lack of co-operation by the staff using the equipment. It is imperative not only to plan every detail of the system, but also to involve the users in every stage of its implementation. Too often, a new system merely duplicates the existing procedures, instead of replacing them.

Fourth, it is evident that for the foreseeable future there will be a marked shortage of EDP unit managers, systems analysts,

programmers and operators. It is equally important, therefore, that planning encompass manpower requirements including staffing, training, recruiting, provision of competitive salaries and benefits, and consideration of probable effects of turnover.

SECTION XIV

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Appendix A

ESTIMATIONS OF SYSTEM REQUIREMENTS

APPENDIX A

Estimations of System Requirements

The following outlines some of the System's capabilities based on commercially available hardware. References are made to some devices, presently being researched, that could greatly expand the System's capabilities.

Specifications for a Five-Year Active Personal Data File

Record Size (in characters)			2,200
Based on:	I.D.	200	
	Five-Year History of episodes (based on 40 char/episode, average of 10 episodes/yr)	2,000	
		2,200	
No. of Records/District			200,000
Based on:	No. of persons/region (approx)	1,000,000	
	No. of persons/district (approx)	200,000	
No. of Characters Stored/district (approx.)			450,000,000
Average Time Available/Enquiry (approx.)			3 seconds
Based on:	150 doctors/district		
	30 patients seen/doctor/4 hr. period		

(It should be noted this approximates the worst case since this number of patients might be seen over a period of 8 hours. This allows more time/enquiry.)

Hardware and software available commercially today are quite capable of storing the volume of data outlined and processing enquiries within the times referred to above. The type of terminals (teleprinters, cathode ray tubes, etc.) and the types of connections (e.g., telephone lines – voice grade, broad band, etc.) must be considered in detail before optimum times may be obtained. The trend to better terminals at lower costs is worthy of note.

Specifications for a Lifetime Less Active Personal Data File

Some studies show that clinical use of records over two years old in their present form is less than 1%: thus data compression and less accessible data storage capabilities might be justified.

Record Size (in characters – approx.)		7,000
Based on:	200 characters/I.D.	
	100 characters/year (compressed format)	
	65 year average	
No. of Reels of 1600 F.C.I. magnetic tape/district (approx.)		60 reels
Based on:	7,000 characters/record	
	200,000 records	
	25 x 10^6 characters/reel	

(Files of this magnitude are not uncommon today, e.g. the master file retained by OMSIP is more than 70 reels).

Obviously, if mass storage devices were available with far greater capacity at reasonable cost, the System's capabilities could be greatly expanded and possibly simplified. Such devices are being researched today, for example, one device utilizing the light interference principle provides single units with a storage capacity of about 100,000,000,000 to 1,000,000,000,000 (hundreds of billions to thousands of billions) characters.

Appendix B

CLINICAL APPLICATIONS OF SYSTEMS ANALYSIS AND SYSTEMS DESIGN PRINCIPLES OF COMPUTER COMPATIBLE LOGIC — E. R. GABRIELI, M.D.

APPENDIX B

Clinical Applications of Systems Analysis and Systems Design Principles of Computer Compatible Logic

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Symposium on Use of Computers in Clinical Medicine
Buffalo, New York, October 2, 1969.

TABLE OF CONTENTS

I. INTRODUCTION

Systems thinking is essentially a concept to co-ordinate efforts within a system. In the field of health sciences, this systems thinking will require:

(a) development of new principles in health care with high priority assigned to integrated functions;

(b) new methods in human information organization, and

(c) adaptation of modern data handling technology for implementation.

Briefly, this calls for a wholesale re-evaluation of our entire health system.

As an introduction to systems thinking, this manual discusses the related issues from both a clinical and an engineering point of view in order to demonstrate that systems thinking is essentially an adaptation of modern operations research to medicine. Thus the objective is limited to providing the reader with essential background information to appreciate this new field. To illustrate our points, many times we deliberately oversimplify complex problems. The purpose is to show the value of this new discipline, and, for the sake of brevity, deliberate simplification was chosen instead of comprehensiveness. The reader should bear in mind that the aim is to outline the typical rather than to present an exhaustive analysis of all alternatives.

Systems thinking is a philosophy and a technology which will soon become an integral part of our clinical attitude. We hope this manual will help to close the gap between systems thinking and clinical medicine.

II. NEED FOR SYSTEMS THINKING

Our present health care practices reflect unplanned evolution. One can easily dissect away the recently introduced medical functions (such as spectacular ear or heart surgery, organ transplantation or vast population screening for genetic disorders) from the basic network of clinical functions of which many have remained

essentially unchanged over the centuries. This peculiar unsystematized mixture of old and new is, of course, the result of rapid progress in clinical medicine during the past few decades. Recent advances in biomedical research have provided us with many new tools in clinical diagnosis and therapy. All efforts were focused on adopting these to routine usage, and too little time has been devoted to reorganization of the entire system. Simultaneously, our social attitude toward the sick has changed drastically during the last decade. Legislators, both at the state and federal levels, responded promptly to these desires by passing bills to institute vast health programmes. All these profound changes occurred in a democratic society which is inherently slow in self-organization. The result is a lack of logical, systematic structure in the health field. The consequence is, however, of great national concern; the staggering cost of health care is coupled with embarrassing inefficiency to produce an incredible waste of our limited health resources.

To illustrate the lack of systematization, let us briefly describe some of our typical operational characteristics in the light of systems thinking.

A typical practitioner, although licensed by the Education Department of the State and increasingly regulated by various professional organizations, is essentially as independent in his activities as the horse and buggy doctor was a century ago. For people to seek a doctor's help only when they believe medical assistance is warranted is basically an improper design because it leaves a fundamental clinical decision in the hands of laymen. Therefore, we had to introduce various methods of mass education for the entire population to urge, for example, self-examination for early breast cancer detection, mental hygiene, and reduction of weight to protect the cardiovascular system. These mass educational efforts are expensive, slow, and often inadequate substitutes for an organized individual health care system for all citizens. However, owing to our limited resources organized health care is inconceivable without very extensive systematization.

Let us continue the analysis of our present practices. When the patient seeks medical help, the practitioner usually renders his services in his office. His office records are informal, kept in his file, often inaccessible, and uninterpretable by anyone but himself. While this traditional arrangement protects privileged information in a very effective manner, it is an expensive method for data handling and, inherently, results in much loss of data.

Since a large part of the clinical data are stored inaccessible in the filing cabinets of the practitioner, the fees for services had to be collected according to another set of records. With the advent of more and more insurance plans, an elaborate bureaucratic mechanism burdening the physician, patient, and, collectively, the taxpayer has evolved to achieve payment for the medical services rendered. It is a dangerous trend that this purely economic structure already has grown greater in size and cost than the health services *per se*.

For the seriously ill, hospitals provide the environment for diagnosis and therapy. The procedure of hospitalization is another example of how the lack of systematization can create unnecessary difficulties. In order to regulate hospitalization, insurance agencies, administrators of hospitals, and others have contributed to the present labyrinth of hospital admission policies by often assigning decisions to admitting clerks who are essentially incompetent to make such decisions. In the absence of systematization, the current hospitalization rules which were evolved out of sheer necessity lead to frustrations and suboptimal utilization of our resources.

In the hospital, the more complex diagnostic and therapeutic functions gradually necessitated development of the clinical chart as we know it today. Recently, hospital accreditation committees have placed increasing emphasis on the format and content of this clinical chart since this is the only way for self-regulation within the hospital as well as the only method for the various state and national agencies to gain some comprehension of the habits and practices of the individual clinician or a hospital. Despite the great cost of writing and reviewing these charts and the expense of the organizing record libraries, the yield continues to be unsatisfactory. No other industry but the health industry would tolerate these record keeping practices.

Not only are our current ways of data handling expensive and sluggish, but they are often outrightly injurious to the users of the health services. In 1968 the estimated national cost of health data handling was over 17 billion dollars.* This estimate is actually rather low and uses only the visible top of the iceberg. Inadequate use of resources and facilities and the secondary wastes due to inadequate care and assistance cannot be calculated readily, but they certainly contribute to the cost of health care.

* (for details cf. Progress Report on Feasibility of Record Linkage, 1969)

Systems thinking reveals the importance of effective data handling. It is often stated by systems experts that the "fuel" of a system is effective data flow. The volume of data generated by the health industry is staggering. For 1970 the anticipated number of prescription drug-related documents will exceed a half a billion within the Medicare-Medicaid system alone.

In terms of systems operation, a substantial portion of the current paper work is redundant. For instance, the expensive filing of reimbursement claims duplicates data previously recorded by the clinician.

While on one hand we frequently duplicate already recorded data, on the other hand inefficient data flow also results in frequent loss of invaluable data. Observations by physicians, nurses, and other health professionals should be preserved and examined carefully for potential subsequent utility.

A cardiac murmur detected by the school physician should be retrievable as a part of the patient's compiled records. In our non-system operation, innumerable information pockets result from the method of filing hand-written notes. Yet, it is generally accepted that 30-32 cents of a health dollar are devoted to recording, storing and copying data.

In a non-system, recorded health data are used for a single short-range purpose. In systems thinking, the recorded data are reutilized. With a practical example, let us show how much redundancy exists in our current paper handling practices. Let us follow the tortuous path of the documents recording the medical event of a delivery:

(1) In a quite detailed fashion the obstetrician describes the medical aspects of the prenatal period in office records and the delivery and puerperal course in the hospital chart.

(2) In addition, for each newborn, a BIRTH CERTIFICATE is required. Here the obstetrician and a record librarian complete a detailed form which is essentially redundant, since the data are in the hospital chart.

(3) In Buffalo, these birth certificates are mailed to the City Hall for compilation of the traditional list of births. This step is another manual copying.

(4) In due course, the accumulating Birth Certificates are transferred to the Erie County Health Department. Here the data are transferred into punch cards for statistical analysis. This is indeed another redundant step.

(5) In time the Birth Certificates are mailed by the County Health Department to the State Health Department in Albany where the records are transcribed onto magnetic tapes for further statistical evaluation. The original BIRTH CERTIFICATES are also placed into permanent storage. In addition a microfilm is prepared by the State Health Department and mailed to the National Center for Health Statistics.

(6) At the National Center for Health Statistics, (via Durham, N.C.) the data are copied once more for a tabulation of national statistics.

This description of the fate of a single document should illustrate the wastefulness of a non-system. Two striking deficiencies are evident:

(a) **expensive recopying** – estimated cost of \$10,000,000 for the duplications per year;

(b) **slow transfer** – the lag at the National Center level is about 18 months. At this pace the information is no longer current and of questionable value to a society developing at the current pace of the United States.

Due to the slow flow, the mechanism allows only historic evaluation without the capability of correcting any deficiency. For instance, a drug-induced injury to the fetus cannot be detected early if the data flow is slow. Great harm can be done to many in the meantime. For monitoring purposes this pace of data transfer is therefore *meaningless.*

Computer-assisted data handling could eliminate problem (a) by dispatching BIRTH CERTIFICATES directly to all the agencies listed above. This would also solve predicament (b) by eliminating the time lag. In order to exploit this capability of the computer, extensive systems analysis and systems design are required. The purpose of this manual is to show how to design a medically acceptable system which also meets the criteria of the various health agencies.

To further illustrate the waste of valuable clinical data let us follow the patient after discharge from a hospital. The clinical chart remains in the hospital, and only a discharge summary, frequently compiled hastily at the time of discharge, will provide the means of information transfer from the hospital to the community system. If the same physician continues to treat the case, data transfer is usually good. As patient care in the hospitals becomes increasingly complex, this informal way of preserving data is less and less effective. Changing physicians and seeking the help of specialists are further sources of data loss. Often the patient's own impression is the chief source for reconstructing the reason for hospitalization, the clinical diagnosis, and the therapy supplied. In our era of television and data transmission via satellites, these archaic ways of data handling are difficult to defend.

While valuable information is wasted throughout our health care system, the burden of red tape on clinical practice keeps increasing. Due to changing social attitude toward illness, the various state and federal agencies request more and more information. These lead to more and more paper work. The practitioner had to learn how he could still function effectively in the face of growing red tape. The typical situation adopted was to transfer the paper work to hired clerical personnel. This further increased the overhead cost. Also, the quality of data generated by these clerks further decreased the credibility value of the data. Moreover, during the last few years the mutual co-operation between federal and state agencies and the practicing physician reached another low point. The data seeking efforts of various governmental agencies are met with suspicion since, during the past few years, the filling out of forms too often led to additional regulatory rules rather than to assistance. The threat of continued restriction is in the air. This threat is more serious than in the past since the health bureaucracy may now enforce rules by simply denying reimbursement. In this non-system situation, the haunted physician is handicapped by the increasing volume of red tape, pressured to do more work, and simultaneously expected to keep up with progress in medicine. Furthermore, the physician is expected to absorb the blame for the failures in various health programs. This erosion of the public image is a particularly dangerous turn in these critical times when the clinician's favorable motivation is imperative for the successful development of national programmes.

The need for systems thinking becomes even clearer if we consider the size of the health industry now operating without any planned or organized system. The scope of this health industry is

substantially larger than the health care system proper. Education, housing, social problems, urban issues, and welfare activities are directly related to medical care. All these areas use health data to a great extent, and effective information flow is imperative for successful operation of these departments.

In the competitive business world non-system operation is intolerable, since the resulting inefficiencies would erode the ultimate justification of the business operation, the profit. In contrast the health industry has become a vast complex, which threatens our national budget while failing to deliver the adequate services which could depressurize many social conflicts. Even this affluent society cannot afford to continue the present non-system operation.

Modern operations-oriented disciplines (e.g., management sciences, operations research, and communication and information sciences) all utilize the concept of SYSTEMS thinking by simultaneously considering all inter-related activities. The objective of the following discussions is to briefly review the philosophy of systems thinking and to show the methods of a systematization procedure.

III. FUNCTIONAL ASPECTS OF A SYSTEM

The concept of systems is longstanding in medicine. In anatomy we refer to the musculoskeletal or cardiovascular system and in immunology we often use the term immune system to describe the cells which are involved in phagocytosis and/or immune response. The neurologist is concerned with the central and peripheral nervous system. Conceptually, such a system is COHERENT by virtue of related functions.

According to organization experts, A SYSTEM IS COMPRISED OF MULTIPLE OPERATIONS WITH RELATED OBJECTIVES, DELIVERING A *WANTED* SERVICE in relation to, but distinct from, the environment.

This concept places top priority on EFFICIENCY. A health system should deliver health care with maximal efficiency, i.e., with fullest utilization of our resources, maximal benefit to the CONSUMER, and fullest satisfaction to the health professionals and other employees of the system. All these qualifications are the

RESTRICTIONS of the system. The available number of physicians and nurses, the existing hospital beds, the current wages, and the labor market status are the parameters, i.e., the environmental restrictions, within which the system must be developed. Efficiency is thus a term relative to these restrictions.

While efficiency is a relative term, the purpose of systematization is to make efficiency as objective, explicit, and quantitative as possible. For instance, in a theoretical system no energy (i.e., time or money) should be lost owing to incomplete co-ordination. The "real world" system, on the other hand, will inevitably operate with a somewhat lower level of efficiency because of the human factor and technical difficulties. Systematization is a scientific effort to control this gap between the efficiency of the ideal and the real world efficiency by utilizing all experience and knowledge offered by all relevant disciplines. For instance, the system is inefficient if a health professional performs duties which could be done by a clerk (cost saving) or by a machine (human resources conservation). The system is not efficient if the hospitalization procedure is not controlled primarily by the clinical need. The system is not efficient if the patient is kept in the hospital longer than medically required. The system is not efficient if the same service could be provided by fewer "health dollars."

Functions in a system once efficiently designed *may become obsolete.* For instance, the complex care system for pulmonary tuberculosis has become obsolete with the advancement of the antibiotics era.

Efficiency should be a measurable entity within the system. For instance, it is quite feasible to calculate the cost of a laboratory test with regard to institutional work load. In a large medical center, extensive automation provides substantial cost saving, whereas in a small hospital automation of the laboratory may not be economical.

Therefore, the system's efficiency should always be expressed in terms of (a) presently available technology ("state-of-the-art" restrictions) and (b) environmental restrictions.

Availability of human resources is a typical environmental restriction. For instance, the present shortage of nurses is a serious problem in the health field. Dilution of nursing functions with administrative or managerial burdens should be examined in terms of priorities. If the nurse is to devote more time to patient care, some of

her non-vocational functions need to be taken over by the system. This would reverse the current trend where more and more nursing functions are transferred to the practical nurse or even to the nurse's aide.

IV. SYSTEMS DISCIPLINE

Efficiency of the system calls for predictable and rational participation and co-operation by all those working in the system. This aspect is often referred to as the DISCIPLINE of the system. Human organization studies showed that this systems discipline required very careful study. For instance, in a large teaching hospital, the house staff usually exhibits admirable discipline when a cardiac emergency team is assembled. The house staff member can clearly see the purpose and is willing to make himself available on a moment's notice to save a patient with a cardiac arrest. The same house staff member will show a much lower level of co-operation with regard to completing his clinical charts. Ingenious motivations and/or threats have been designed by the various Record Room Committees to elicit better co-operation.

A system can remain efficient only if all the participants, i.e., consumers as well as those providing services, remain motivated. The importance of this psychological aspect cannot be overemphasized. Disagreeing, dissatisfied, or disinterested participation will rapidly erode the rules of the system and lead to increasing inefficiency. Discipline of the system limits certain functions. The system can be successful only if the participant is willing to impose the functional restrictions on himself.

V. INFORMATION HANDLING

Computer technology has truly revolutionized the organization-oriented disciplines by greatly increasing data storage and retrieval capabilities. While systems thinking is the scientific co-ordination of activities, the means for implementing this aim is highly efficient data handling.

DATA is the general term encompassing all facts and impressions related to health. For instance, the patient's age, sex, race, height,

weight, nationality, occupation, etc. are all data. Information, on the other hand, is a specific datum which affects the clinician's judgment. Therefore, information is DATUM-CUM-MEANING. This essentially inductive, purely scientific, empirical approach assumes that a finite number of related data provide the full array of information necessary for diagnosis, therapy, and prognosis. Information is a potential capability of data to serve as the basis for "best" clinical decisions. Data lacking this capability "noise," should be suppressed by the system. INFORMATION in this context, "signal," is the property of the datum to alter decisions concerning diagnosis, therapy, and prognosis.

The data may be ranked as to various levels of pertinency to the physician in his development of a diagnostic opinion. The specific purpose of data analysis is to establish the list of pertinent data, i.e., the array of information necessary for "best decisions." Hypothetically, we can establish the diagnosis of hyperthyroidism in the possession of the *full* array of information proving the presence of hyperthyroidism and excluding other possible diagnoses. In real life, however, the diagnosis of hyperthyroidism is often safely made on the basis of *less than the full array* of clinical and laboratory information. The objective of the system is to standardize the scope of information acquisition and thereby optimize the decision system. Closer study of this issue shows that clinical information must be quantitated in terms of diagnostic value in order to design an effective diagnostic data system.

Using the methods of communication sciences (cf. Workshop #8) the rationale of information handling will be enhanced, and soon we shall be able to calculate the exact information contained by a datum. Then, we can calculate the cost per unit of information, and, step by step, medicine can become an exacting science like chemistry or nuclear physics. Computer technology will give the necessary methods for developing the quantitative aspects of clinical information sciences.

In traditional medicine, information is used for the short-range purpose of diagnosis, therapy, or prognosis.

In a systems approach, information not only has this short range utility value but also is of great importance to the patient. All information is permanently filed in a patient's dossier. This concept is often referred to as "record linkage," (cf. Workshop #6). In such a system all previously recorded data of a person can be easily

retrieved. Availability of such clinical files from birth to death will enable the clinician to develop his best diagnosis in the light of all previous clinical data.

Recorded information has substantial utility value beyond the outlined use. For instance, the psychiatrist's opinion should guide the judge when reviewing the case of a chronic alcoholic, or the social worker should be assisted by the data accumulated in the clinical chart. Obviously, neither the judge nor the social worker should receive a copy of the hospital chart. This would be an ineffective information transfer. Only *pertinent* information should be transmitted to the judge or the social worker in their particular language. The scope of this selective information transfer is a particularly interesting new challenge.

When information transfer is poor, duplication is not only expensive but also often of lesser quality. Lacking the full psychiatric evaluation report, the social worker assesses the patient anew. Conversely, though a fully detailed social evaluation exists elsewhere, the clinician has to include social history data as he develops his diagnostic impression. *Within a system, all information once recorded is preserved and exploited by all who could reach a better decision if more fully informed.*

Data flow within the system requires careful planning with appropriate security measures in order to:

(a) **protect the patient**, the source of privileged information. Only authorized "users" of the system should have access to certain data. A clinician should have access to his own patient's records but should not be able to read another physician's data. This type of safeguarding is well within the capabilities of modern computer technology;

(b) **protect the data providers**, e.g., physicians, nurses or social workers. All "users" of the system must be confident that the data recorded will not be used against them. For instance, diagnostic errors are detected, recorded and stored by the system for self-improvement purposes. A physician can then compare his own success rate with the community average. It is imperative, however, that this kind of data cannot be used by others to evaluate a physician. *Full immunity must be assured* for candid recording. The purpose is educational and not punative.

It is also important to develop an effective data flow to *exploit* the potential information value of the recorded data. For example, a number of clinical specialties treat urinary tract infection. The system should provide a summary of all experiences concerning effectiveness and adverse reactions of the various antibiotics. This sharing of therapeutic experience within the system enables the clinician to choose the "best" drug, in the light of his clinical findings and the provided drug experiences. This calls for a *DATA BANK* containing data on the courses of all drug treatments. Information acquisition and recording must be uniform in order to "pool" data. Standardization of recording data is imperative for the establishment of a data bank. Uniform data recording is not a restriction, but actually, an assurance of comprehensive records. The details of this issue are extensively discussed in Workshop Manual #5.

VI. REAL-TIME COMMUNICATION AND SELF-ADJUSTMENT

Communication is information transfer from the "sender" via a "medium" to a "receiver." Effective communication is another critical criterion of a system. Any data recorded within the system should be readily available to all authorized users. This is not only to eliminate duplications but also to reduce communication time. Current information enables a receiver to interact with the event whereas historic information is of value only for future similar situations. This line of reasoning leads to the concept of "real time." In communication sciences real time use of data is defined as *acquiring and processing the data rapidly enough to affect the course of the event per se in light of these processed data.* For instance, the directional measurements of a rapidly moving space craft must be processed fast to direct control of its course. In a constantly changing dynamic system, real-time measurements can control the entire operation if processed rapidly enough.

Continuous real-time self-evaluation results from effective communication within the system. Computer technology can provide us with the necessary hardware. The systems design will be such that this continuous self-improvement or self-correction should be the cornerstone of the system. Once this is fully realized by all participants, unqualified co-operation will follow.

VII. COST CONSIDERATIONS

It is generally believed that systematization with extensive use of computers, informationists and systems programmers is an extremely expensive undertaking. But, considering the wastefulness of a non-system, the use of these new tools is an absolute economic necessity. We have estimated that the current direct cost of health data handling is about 17 billion dollars annually. This could be fully automated throughout the country for less than 3 billion dollars. Moreover, a fully computerized health care system would operate at a much higher level of efficiency. Such an improvement cannot be expressed readily in terms of cost saving. For these critical times when every citizen's constitutional right is to receive adequate health services and when the human desire to improve social conditions has gained such momentum, *systematization is not only urgent economically but also imperative for a social arrangement where both the consumers and the health services providers can function comfortably and effectively.* Without systematization health services expected from Medicare-Medicaid are economically impossible and frustrating to all parties. A successful systems approach could motivate both consumers and service providers to a higher level of co-operation.

The first years of Medicare showed the methods of self-improvement in a non-system situation: mass accusation of the medical profession, drug manufacturers, or other groups, and mushrooming of bureaucratic control systems with traditional clumsiness. These methods may reflect frustrations but certainly will not lead to motivation, co-operation, and enhanced effectiveness. The elicited resistance is good evidence for this claim. Systematization requires considerable effort by knowledgeable, dedicated planners, and full support by the appropriate agencies. However, systematization of health services will open up new horizons in our society. Any further delay may lead to continuous confrontations and discord and produce more and more hostility and frustration on a national scale.

VIII. PRINCIPLES OF SYSTEMS ANALYSIS

1. Scope of the Health Care System

The entire health system is too large to discuss effectively. To deal with it in an organized fashion, we first have to outline the scope in

the form of major units, SUBSYSTEMS. A subsystem is a major component capable of carrying out its full task nearly independently. Without a tight system the individual subsystems tend to strike for independence, a typical source of waste. It is commonplace to use the cardiac team to prove the issue. In several larger cities, open heart surgery is performed by a number of heart teams each using very expensive equipment and resources insufficiently to justify its cost. Hospitals, "empire building" large medical centers, and health departments often show symptoms of independent subsystems.

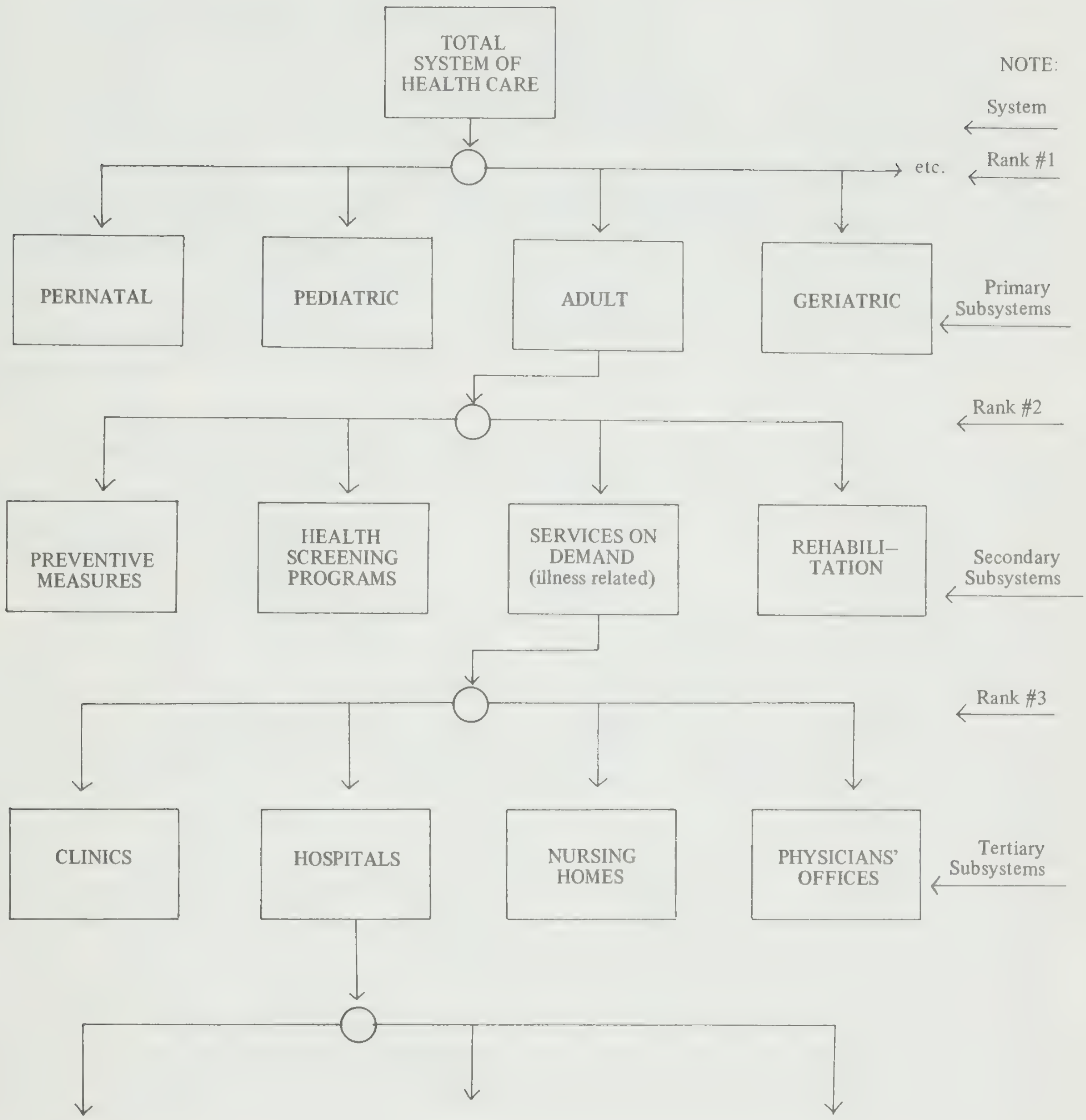
In order to explore a large system we often apply a FACTORING procedure. There are no firm rules for factoring, and any logical segmentation serves the purpose of developing an initial schematic depicting the hierarchical structure. For instance, the total health care system can be divided into four major segments, as shown in the following diagram. Each primary subsystem can be followed through its secondary subsystems. The ADULT segment can be further factored into four subsystems, and the SERVICES ON DEMAND segment can be again subdivided into four "tertiary level subsystems," viz., CLINICS, HOSPITALS, NURSING HOMES AND PHYSICIANS' OFFICES. Hospitals can be further subdivided into general and special hospitals or private and government hospitals, etc.

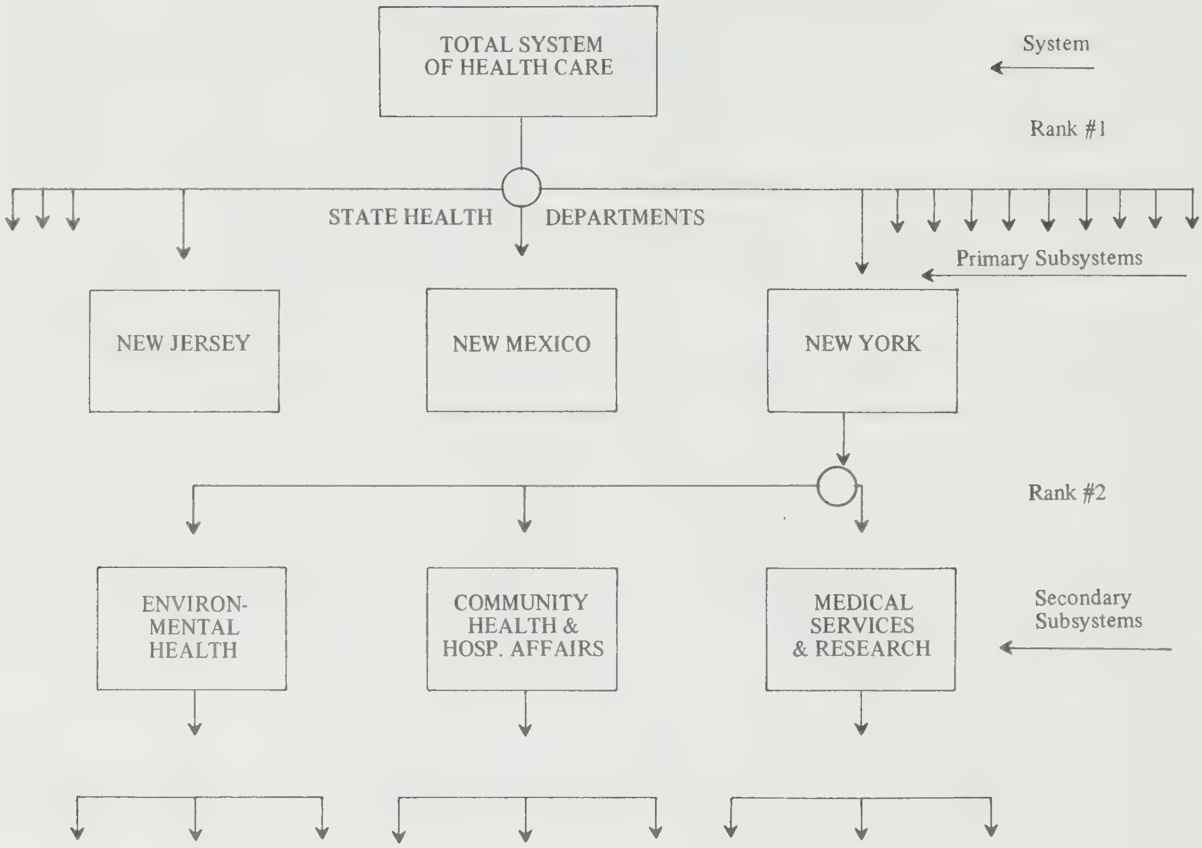
Once the comprehensive operational structure is defined, we can begin examining the internal efficiency as well as the effectiveness among the subsystems within the vertical and horizontal correlations.

Factoring is, in essence, a didactic exercise simulating our own way of organizing data in our memory. Priority of ranking or the division of larger subsystems is often a matter of preference. The scope as well as the wanted function remain identical, but the factoring may reflect our reasoning with regard to the environment. For instance, the entire health care system may be presented with emphasis on the regional geographic aspects instead of dividing the system by the age group of the patients as in the following design.

If socio-economic, climatic, geographic, or genetic factors are in the forefront of our interest, we may design a different set of blocks although we are actually slicing the same cake in different ways.

The actual scope of the health system is substantially larger, infiltrating many related fields embedded in the environment. For instance, education of health professionals – education for care of older citizens – welfare – Department of Defense – military


TOTAL
SYSTEM OF
HEALTH CARE
NOTE:
System
etc.
Rank #1
PERINATAL
PEDIATRIC
ADULT
GERIATRIC
Primary
Subsystems
Rank #2
PREVENTIVE
MEASURES
HEALTH
SCREENING
PROGRAMS
SERVICES ON
DEMAND
(illness related)
REHABILI-
TATION
Secondary
Subsystems
Rank #3
CLINICS
HOSPITALS
NURSING
HOMES
PHYSICIANS'
OFFICES
Tertiary
Subsystems


TOTAL SYSTEM OF HEALTH CARE
System
Rank #1
STATE HEALTH DEPARTMENTS
Primary Subsystems
NEW JERSEY
NEW MEXICO
NEW YORK
Rank #2
ENVIRON-MENTAL HEALTH
COMMUNITY HEALTH & HOSP. AFFAIRS
MEDICAL SERVICES & RESEARCH
Secondary Subsystems

medicine – racial issues – population screening, – etc.

2. Methods of Systems Analysis

Systems analysis is a co-ordinated effort to determine the objective of the subsystem, the involvement of human resources, the use of physical facilities, the human interactions, the data flow, and other operational characteristics. This is not a time and motion study to save effort but is a comprehensive description of the current practices. Systems analysis is a formal function requiring a team conducting the analysis and the full co-operation by the subsystem for effective data gathering.

In some medical quarters the misconception prevails that systems analysis is a first step to be carried out by the computer salesman prior to the installation.

Actually, a systems analysis of a clinical situation *requires a team* headed by a senior physician and including professionals very familiar with the operational details. Systems analysis of a hospital cannot be assigned to a typical systems analyst, since the planning and interpretation of the data requires rich experience in hospital functions and sensitivity to medical pressures. In terms of specific knowledge seasoned clinicians are necessary to direct the analysis. The team should include operations research engineers and management experts as well as students of behavior sciences. Some of the mathematical capabilities offered by these disciplines are modeling for scheduling, queuing, logistics, information and communication sciences and technology, game theory, inventory science, formalization of decisions, human organization and man-machine interface planning.

The process of systems analysis produces a detailed presentation of current operations. It is important to bear in mind, however, that the level of insight provided by such a systems analysis is limited by the professional competence of the team. The medical aspects of the operation research cannot be at a higher level of sophistication than the input of the medical members of the team. The intellectual content of the product depends on the participants. Similarly, the other members' professional input will limit the other aspects of systems analysis. With this in mind the members of a team should be chosen according to the type of the problem. A bill problem or inventory study requires a different composition of systems analysts than a document design for surgery or discharge record design for psychiatry.

Systems analysis is a time consuming, laborious project. Even a relatively small issue may require 50-100 man-hours, whereas a larger analysis required hundreds or thousands of man-hours.

Physicians and nurses should insist on participating in the work of systems analysis teams whenever their function is even indirectly related to the area of analysis. In the hospital setting, every aspect of the institution's operation, even parking lot or laundry functions, is indirectly or directly related to the medical aspects. Without the physician and nurse, a systems analysis team may recommend solutions conflicting with medical, nursing, or patient interests. For a physician or a nurse to be an effective member of a systems analysis team requires a few days' training whereas to make a seasoned clinician out of an industrial engineer would require two or three decades. The following brief outline of methodology is prepared to bridge the gap between the technical textbooks and everyday clinical medicine. For more details the appropriate textbooks should be consulted.

3. **Modeling**

Communication between two disciplines becomes increasingly difficult as overlapping competence diminishes. Clinical medicine with its many facets is difficult to present to the industrial engineer who has no corresponding experience. Similarly, the mathematical models, the concept of linear programming, or other terms familiar to the systems oriented industrial engineer, mean little to a nurse. Terms used by a discipline require the related information for appreciation. Out of context they are meaningless terms. And to dissect terms out of context to facilitate the transfer of information is exactly the objective of modeling. Communication and language will be discussed extensively in workshop #5. Here it may be sufficient to state that modeling methodology is a highly effective bridge in communication between disciplines without overlapping competence. Modeling is an information presentation distilling away much of the context data and retaining the abstract thought process fully perceivable by another discipline.

(a) **Iconic Models** are the simplest models where similarity to the "real world" is preserved. A cross section of the kidney showing the renal cortex, medulla, and pelvis in the textbook of anatomy is a characteristic example for an iconic model: a two-dimensional illustration with substantial simplifications to demonstrate the position of the glomeruli and tubuli. A

somewhat higher level abstraction is the *schematic* iconic model of a single nephron showing the excretion and reabsorption processes related to the anatomic structure. Here, for the sake of lucid demonstration of the renal transport mechanism, the anatomic structures may be shown in disproportionate scale. The accuracy of the structural elements is sacrificed to better illustrate the function. Architectural designs are further examples of iconic models. Here, some drawings may attempt to simulate three-dimensional appearance.

(b) **Analogue Models** are even further removed from real life; the external appearance of the components involved is even less realistic. After the physical facilities as well as the operational aspects have been carefully studied, certain characterizing properties of an operation are represented by another set of physical forms. This model may show little or no resemblance to the system it represents. A typical analogue model is the cardiovascular model often assembled in a physiology course. Rubber tubes, clamps and a mechanical pump are the major components. Quantitative as well as temporal correlations are particularly appreciated in this type of modeling. By increasing the "cardiac output," i.e., increasing pump efficiency, the secondary changes caused in blood pressure, blood flow, organ perfusion rate, etc., can be studied. As we learn more about abstracting functions and deriving conclusions from such analogue models, we will find analogue computers more and more valuable in clinical medicine. For better analogue models, more accurate data are needed. For instance, there are several quite sophisticated analogue models now described in the literature on anesthesia or on thyroid hormone secretion. These are often referred to as SIMULATION models. As more accurate kinetic data become available on organ, liver, and kidney flow and blood level monitoring improves, simulation models of the anesthesia subsystems on an analogue computer may become a practical "real time" guide for the anesthesiologist while the patient is on the operating table. The anesthetist can check the possible consequence, in terms of blood pressure, renal blood flow, or any other variable included in the model, if the current rate of supply of the anesthetic is continued for 10 more minutes. The analogue computer can present the composite picture of all variables and provide the anesthetist with an accurate forecast. The accuracy depends on the correctness of the kinetic model. Although existing analogue models are mainly research tools, several such models will undoubtedly be a part of clinical medicine within a few years.

(c) The third type of modeling is of particular importance for systems analysis. This model is completely abstract, exhibiting no relationship at all with physical appearance. This type of model is often referred to as a **Symbolic Model.** The flexibility and information transfer capability of this model is remarkably powerful. It is submitted that all physicians and other health professionals should learn to use this type of modeling. A few hours of practice can make anyone an expert model designer. This approach distills away all context information, connotations and medical background knowledge, retaining only persons, actions, time and decisions. This symbolic language is fully understandable by the other, technically oriented members of the systems analysis team. Symbolic modeling is an effective communication language between health professionals and computer-oriented data processors. The following outline represents the symbolic language developed in our hospital and should not be interpreted as an official language. It has, however, proved very effective in interdisciplinary communications, and we think this type of modeling will be found valuable for clear communication while developing a computer-assisted system.

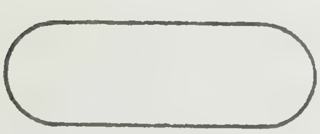
In symbolic modeling a certain well-defined meaning is assigned to a symbol. Extremely complex decisions and multistep thought processes can be explicitly described with such symbols. These may come from clinical medicine, behavior sciences, or computer technology. A coherent presentation of such a model is a FLOW CHART. The most essential operational steps can be presented with great clarity and in a context-free manner, comprehendible even by those completely unfamiliar with the scientific discipline involved. For instance, if we indicate that in possession of 3 specific data a fully rational decision can be made, whereas in absence of any of these only a decision with some uncertainty can be expected, we have EXPLICATED a difficult diagnostic decision. This mental process of removing the context to reduce the decision until it is dependent only on these three factors is in conflict with our traditional education when all the POSSIBILITIES are listed to make decisions academically correct.

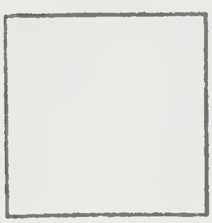
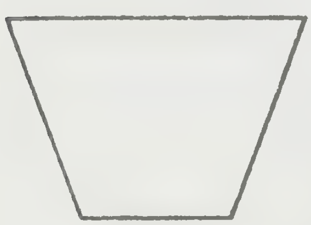
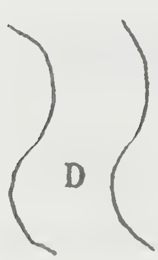
In real life, as well as in symbolic modeling, PROBABILITIES are utilized for effectiveness and expediency. This does not exclude the less probable pathways, but ranks the paths by real life occurrence. Let us look at the problem of repairing a television set. Experienced repairmen develop a sequence of tests.

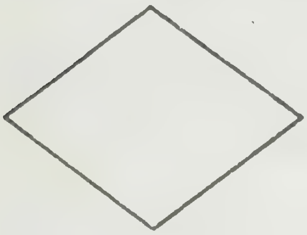
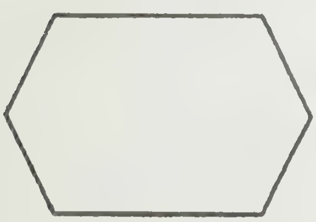
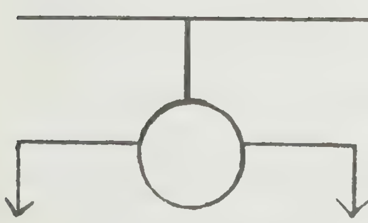
They first check the most frequently failing component and move systematically from possibility to possibility, but according to a probability ranking, until the trouble is pinpointed. In clinical medicine, the experienced clinician usually establishes the diagnosis with a minimal number of steps, using past experience as a basis for a PROBABILISTIC approach. In symbolic modeling this mental discipline is perhaps somewhat difficult at first, but once learned it is of great value. The clinician, inexperienced with this methodology, is first quite reluctant to accept this method of explicating, i.e., step by step simplifications until standard symbols can describe the entire process. For instance, when we offered to assist a psychiatrist in flow charting his thought process when he received a telephone call on a suicide attempt, the clinician was first doubtful, then outright resentful, that the "innumerable possibilities" could be entirely reduced to a few symbols.

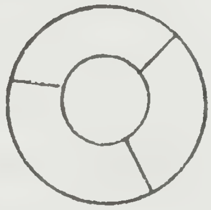
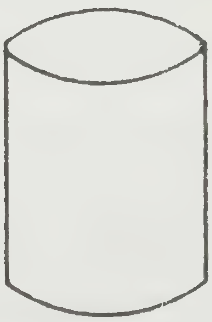
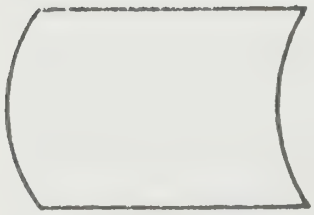
Flowcharting is a graphic presentation of the salient steps in a process. The symbols state the *involvement of various persons;* define *their competence level;* describe *the data acquisition;* which lead to *decisions;* followed by *action(s);* in time dimension; recorded on specific *documents.*

The emphasis is on where who does what – exactly the elements of systems analysis. The symbols presented here originate from computer-oriented flow charts. Our contribution is only to provide the medical content information wherever applicable. The following symbols have been used in our systems analysis efforts:

SYMBOL	MEANING	COMMENTS
	start or stop	This often indicated dead-end paths with no further steps along this line.
	Off-page sign	A process to be described is, of course, preceded by steps, and the process will continue in steps which are not the concern for examining the

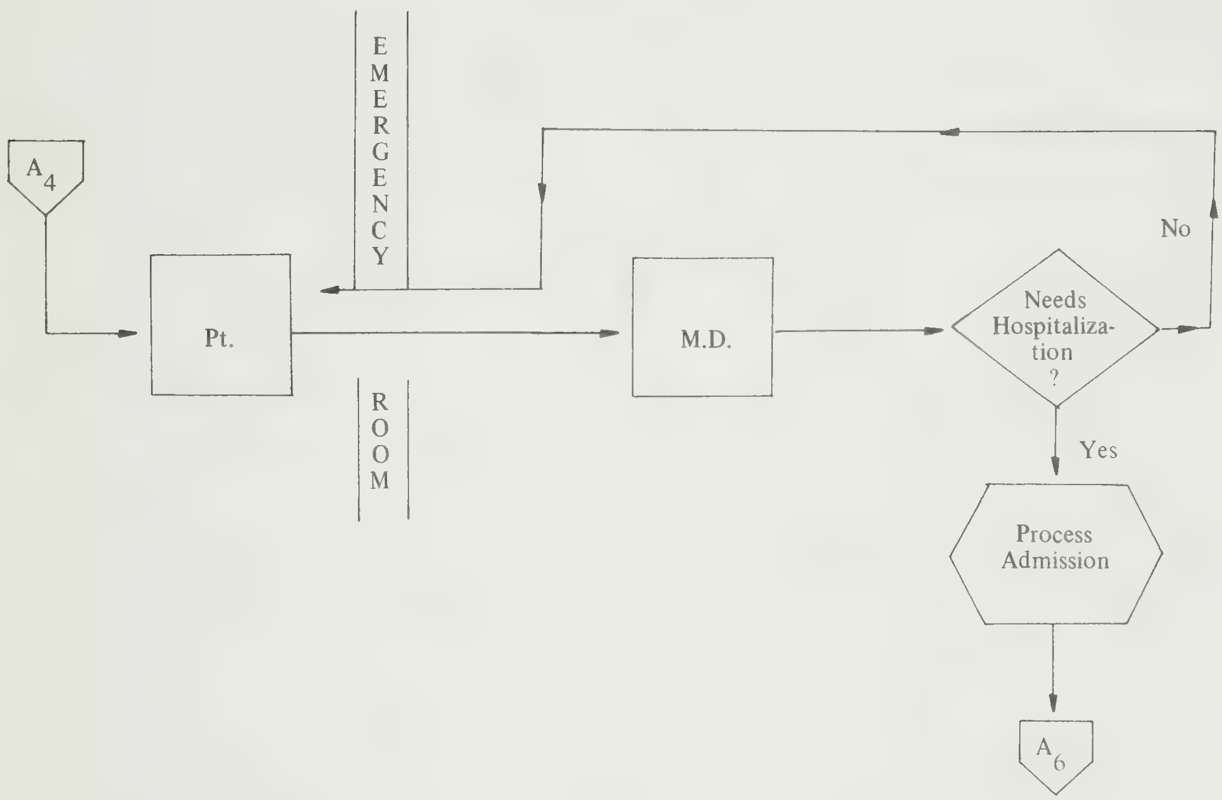
SYMBOL	MEANING	COMMENTS
	Off-page sign (cont'd)	process in question. Off-page signs indicate that we artificially start our model at this point, or end our model at this point. For further details see another flow chart as indicated inside the symbol. The function parallels information stated at the edges of a map indicating where the adjacent areas can be found.
	Person	This may be defined in general terms, e.g., a physician (M.D.) or can be very specific indicating which particular physician is involved.
	Data acquisition	This may be history taking, observation or measurement, e.g., laboratory test. The scope of data must be specified as analysis progresses.
	Delay	This represents a break in the time dimension. For instance, if a test or observation requires a certain time lapse, the diagram indicates a discontinuity of the process. As analysis progresses the typical time delay must be specified.

SYMBOL	**MEANING**	**COMMENTS**
	Decision	This is, perhaps, the most important symbol. Many of our medical decisions actually represent a chain of decisions. For instance, the decision to hospitalize a case contains at least 5 decisions. A decision symbol always contains a question and the sign "?" is always included. The outcome of a decision is typically a YES or NO, or, > or <, (greater than, or smaller than). In some instances a third answer is also acceptable which is neither YES or NO, but somewhere in between.
	Implementation	Represents a well-defined action to execute the decision.
	Event flow	This is also the chain of thoughts, chain of events, a one-way street in the diagram. The arrow at the end of this line indicates the direction.
	Branching	Sometimes several steps occur simultaneously and the flow of events is represented by the symbols at the tips of the arrows. Branching may lead to 2, 3, or more symbols.

SYMBOL	MEANING	COMMENTS
	Information flow	This symbol is used when event flow is not the same as information flow.
	Document	Data are recorded on some form. This may indicate actual manual recording or any other form of entry of data into the computer.
	Punch card	These are various computer-oriented storage media.
	Paper tape	 Film
	Magnetic tape	 Drum
	Disk	

Let us begin the practice of flowcharting with a simple example to illustrate the use of these symbols.

FLOWCHART
A_5

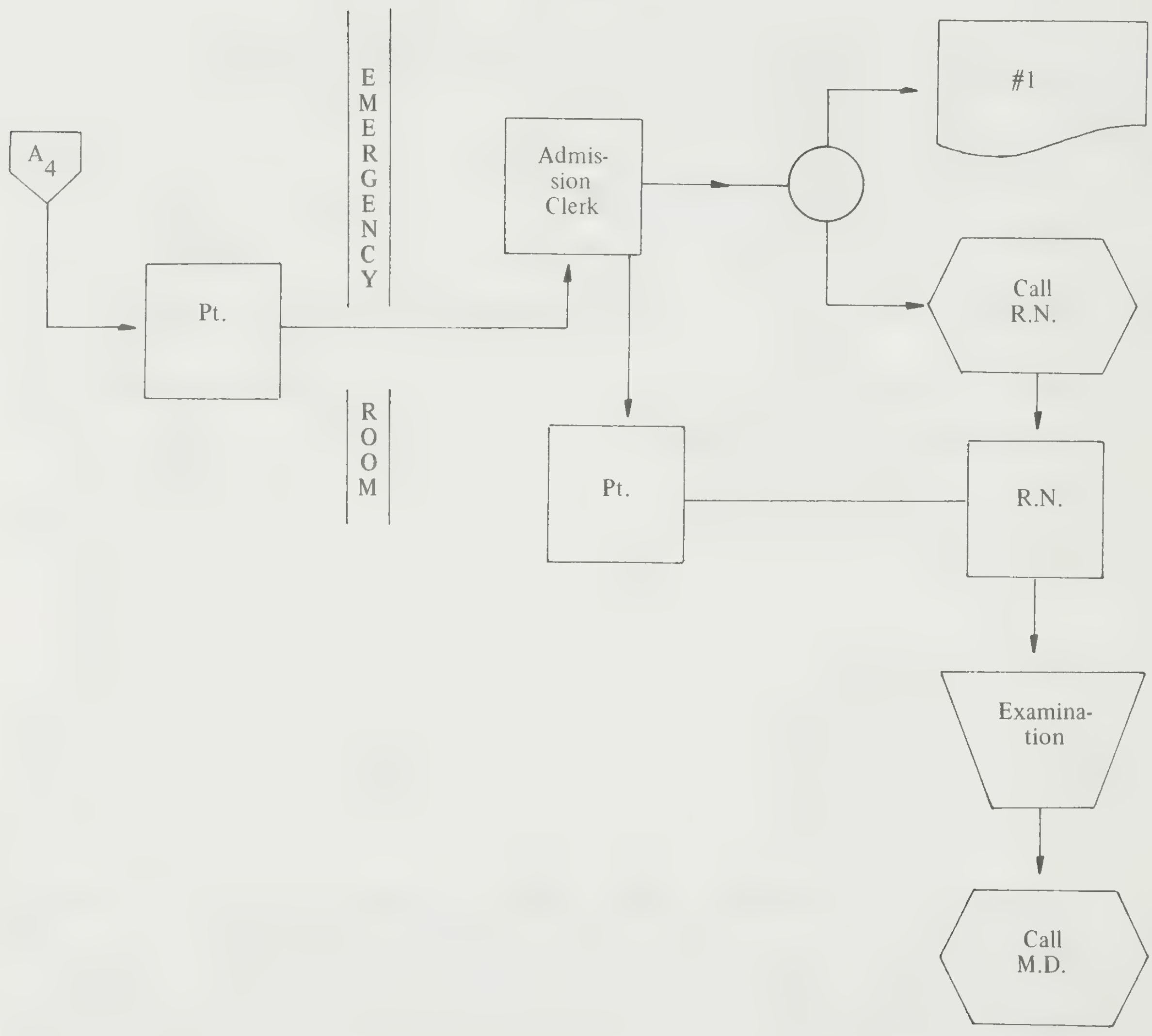


This simple flowchart begins with Off-page sign A_4 indicating that the story we are studying begins when the patient enters the emergency room. All events preceding this step are shown on flowchart A_4 where the role of the ambulance, the events between the accident, and the entry of the emergency room are described in detail. A physician (note the absence of specific data which physician, hence his competence definition is also lacking) makes a decision: NEEDS HOSPITALIZATION? The outcome of this decision is either YES or NO. If NO the patient leaves the emergency room, whereas the YES outcome will be followed by implementation, i.e., processing the case through the admission routine. There, off-page symbol A_6 indicates that subsequent steps are described in flowchart A_6.

Soon this simple flowchart proves inadequate. Several other

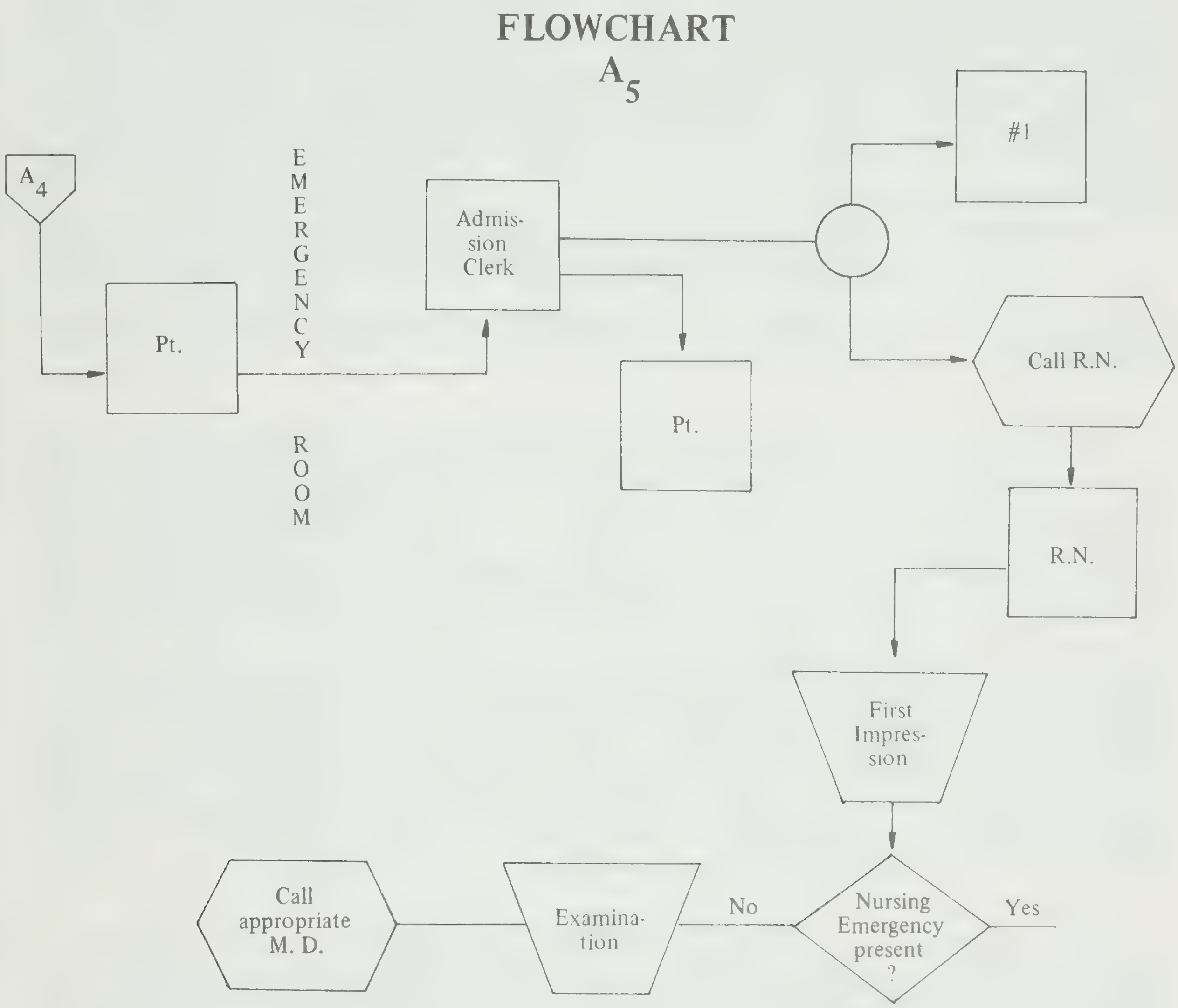
people will be involved, e.g., the Admission Clerk and the EMERGENCY ROOM Nurse. Systems analysis revealed that the chain of events is far more complex than the first flowchart has indicated. Therefore, we design a more detailed flowchart as follows:

FLOWCHART
A_5



This incomplete diagram (note: no terminal symbols, e.g., Off-page or STOP symbol at the lower end) shows that the Clerk is any of the Admission Clerks, with no preference, meets the patient, issues a document (the Admission Form), and simultaneously notifies the nurse about the presence of a patient. According to this design, no specific nurse is indicated to receive the message that a patient has entered the emergency room. At this, numerous finer

details emerge, shown on the next diagram.



This design recognized that the nurse has certain competence to act on an emergency basis. For instance, if the patient's extremity is bleeding profusely, the application of a tourniquet is an emergency step performed by the nurse. Also, if the fracture is unsupported and causing severe pain, the nurse will position the extremity to reduce the pain. This diagramming, of course, calls for joint meetings between the systems analysis team and the emergency room physicians and nurses to develop the catalogue of emergencies necessitating nurse's action prior to any medical involvement. The analysis of this particular step also reveals the necessity of substantial medical and nursing input to define current practices. While at it, the same team will inevitably begin to DESIGN a better system. The bottlenecks, deficiencies and/or information barriers become quite apparent during the course of this analysis, and a PRESCRIPTIVE

attitude evolves.

The team may involve the appropriate senior members of related departments to develop the optimized procedure. For instance, if there is an obstruction of the airway, what is the proper measure to be taken by the nurse? Should she check the tongue and the throat to attempt to alleviate the obstruction, or should she call the nearest physician? Obviously, this depends on the institutional organization. The PRESCRIPTIVE approach would assign more responsibility to the nurse in a small rural hospital than to one in a medical center with interns and residents permanently located in the emergency room area.

At this point, the student of systems analysis should discover the most important reason for carrying out a formal study of present practices. Questioning the emergency room nurses and the director of the emergency room, both ardent supporters of systems analysis, revealed how such important issues are lacking formal definition. It has been up to the judgement of the emergency room nursing staff to follow the course of their choice. These nurses would, of course, welcome a carefully designed institutional policy describing in detail the preferred course of action in case of the four recognized nursing emergencies. (It was also surprising to find how well these emergencies can be defined).

The next issue is "EXAMINATION" of a patient. This may range from reading the referring physician's note requesting admission and stating the diagnosis to a case with no recent medical examination record seeking hospitalization. In this county-supported hospital the institution's policy is to admit all those requiring hospital care, so many patients come to our emergency room directly, without any medical referral. The nurse should decide which of the physicians should be called. As an example, in our hospital a fracture is treated one week by the general surgery resident and the next week by the orthopedic resident. (This is an institutional tradition to provide the residents in General Surgery with some experience in fracture therapy.) Our systems analysis team encountered here again the same problem to which we have become so accustomed over the years. Here is a very important decision made many times daily by our nurses, and our team had great difficulties in verbalizing the problem. We have lacked clear institutional policies separating departmental responsibilities. Who should see a gastric hemorrhage first? Or a cerebrovascular accident? Many of these issues required several meetings with the respective department heads to clarify the

preferred policy. The team developed great admiration for the emergency room nursing staff for their fine record of performance without supporting guidelines. Once, however, systems-thinking demonstrated the advantages of planned operations, we felt about these issues somewhat as we feel about the ancient Greek navigators. We admire their skills but prefer the compass and radar technology for our own safety.

Further development of the admission flowchart

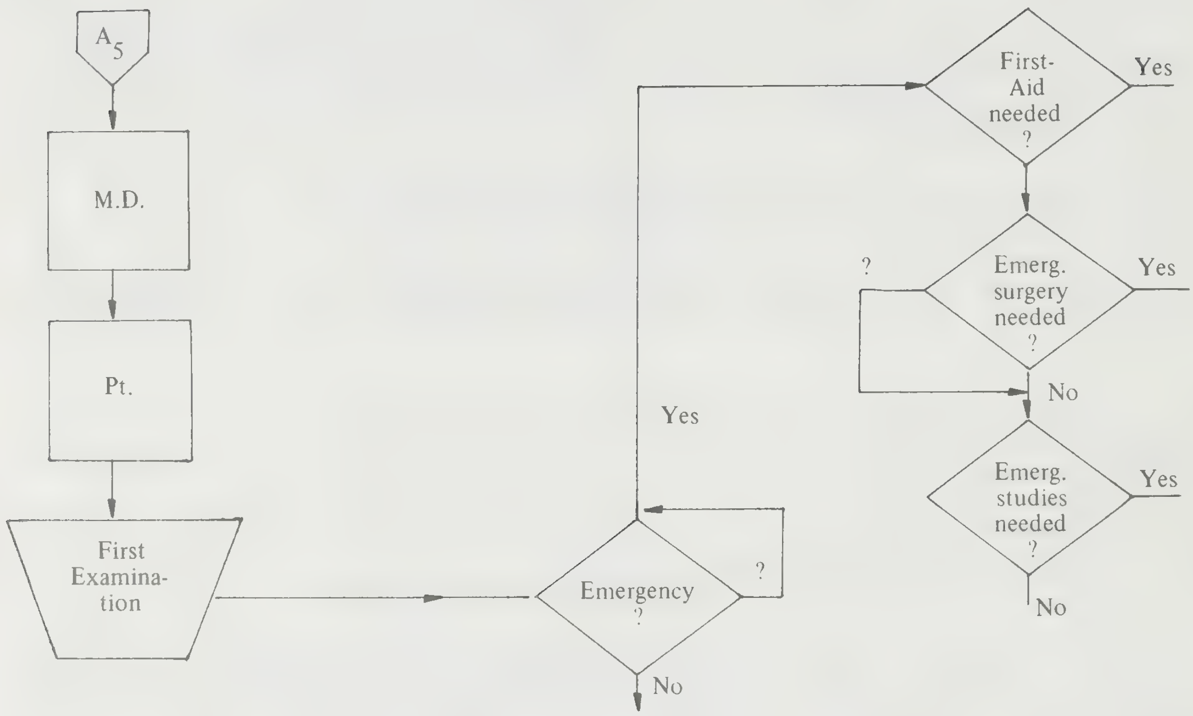
At this point, several major areas became discernable in the POST-A_4 event flow.

(1) Admission Clerk's function
(2) Nurse's function
(3) Physician's function
(4) Possibly other person's function.

The admission Clark's function is continued in workshop 2A, and the Nurse's function is developed in workshop #7. Therefore, let us pursue the analysis examining the physician's role. Since in this hospital, 17 hours of the day (4pm-9am) the surgical resident is in charge of the Emergency Room, let us examine the functions of this particular physician. (Flowchart A_6 on the next page.)

The surgical resident's first concern, after some minimal information acquisition, is to rule out the need for any immediate action. In terms of information technology, the physician should exercise a thought discipline and even if completely inapplicable, the dividing decision leading to or bypassing the "emergency loop" should be routinely included in the procedure. This normative approach calls for an ANSWER TO THE QUESTION: EMERGENCY DIAGNOSTIC OR THERAPEUTIC MEASURE REQUIRED? YES □ NO □. It should be emphasized here, that the development of a detailed flow chart is not an academic exercise. Once fully developed (a) the flowchart is our information map and any further discussion with other members of the planning team can refer to a specific point, as on an architect's draft, (b) non-clinical participants of the analysis can clearly understand the spatial and temporal relationships, and (c) the computer-compatible data input can be closely tailored to correspond in sequence to the flowchart. Therefore, as the architect's first sketch is the first representation of his efforts to express the needs of a client, the flowchart of the systems analysis is the first step toward building a computer-assisted system.

FLOWCHART
A_6



In a computerized clinical system the four basic steps, viz.,

(1) data acquisition
(2) data organization (diagnosis or prognosis)
(3) decision
(4) action (therapy)

are organized in a systematic fashion. The scope of data acquisition should include the pertinent data to enable the decision-maker to reach a SCIENTIFIC DECISION (cf. workshop #5). The flowchart dissects (EXPLICATION OF PROBLEM cf. Manual #2A). The basic facts leading to the decision must be (a) compiled, (b) included in the structured data input form, and (c) tested for completeness and acceptability by users of input forms. The first point of data acquisition is clearly stated in the above diagram. The surgeon, after a superficial data acquisition, enters the first decision point: ANY EMERGENCY PRESENT? This question requires a policy list of emergencies in order to control the content of the term EMERGENCY. In this institution, (cf. Workshop Manual #5) the following surgical emergencies proved to be important:

(1) Airway obstruction
(2) Acute severe hypoxia
(3) Shock
(4) Burns
(5) Coma
(6) Fracture
(7) Acute poisoning
(8) Open wound
(9) Acute pain and/or vomiting
(10) Bleeding
(11) Others

Although this list covered all of the emergencies during the 6 months' period of analysis, by assigning still another category, "others," we EXPLICATED emergencies, at least in a qualitative manner. The resident is expected to look through this list prior to making the first decision: EMERGENCY DIAGNOSTIC OR THERAPEUTIC MEASURE REQUIRED? NO □ YES □ . . . .

At this point we accomplished some other things perhaps not immediately apparent to the uninitiated:

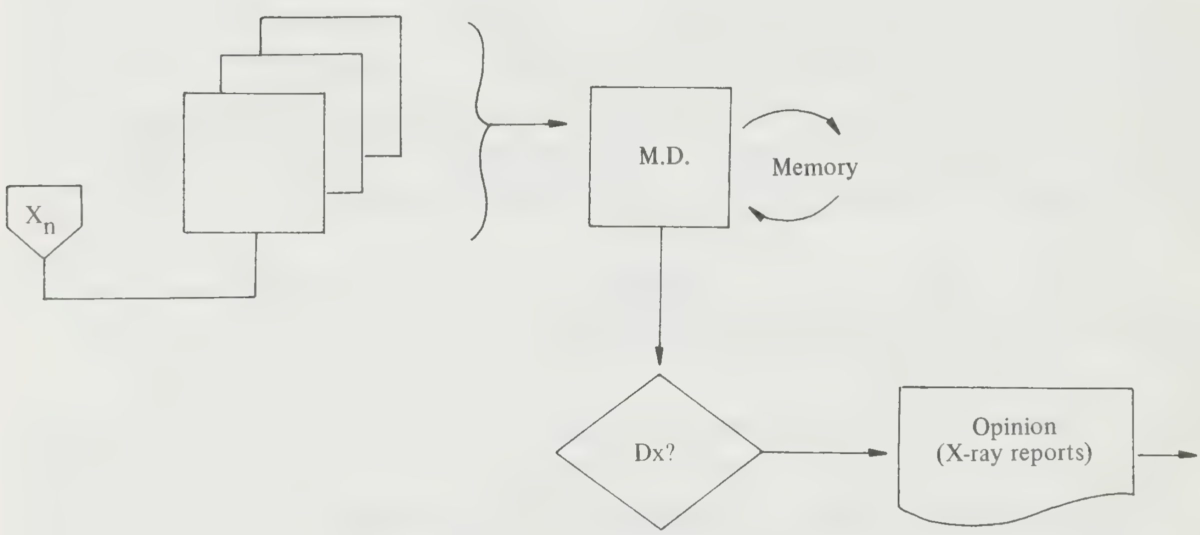
(a) We have recorded a medical judgement for the system as to the possible presence or obvious absence of any emergency. This could trigger further messages to the emergency room nurse and admission clerk guiding them in their own work. Presence of possible or definite problems requiring immediate action should alert the emergency room personnel. If a computer-terminal would make this decision accessible to those (nurse, clerk) who would benefit from this information, the computer could automatically make this available in the appropriate language;

(b) We have implanted a quality control point in our flowchart. The physician makes this decision every time he examines a patient in the emergency room, whether he is aware of it or not. By asking for the outcome of this decision we can not *monitor* the correctness of the diagnostic judgement. Another important medical aspect of flowcharting is to dissect out the decision point, develop the list of supporting data for this decision and study the feed-back loop.

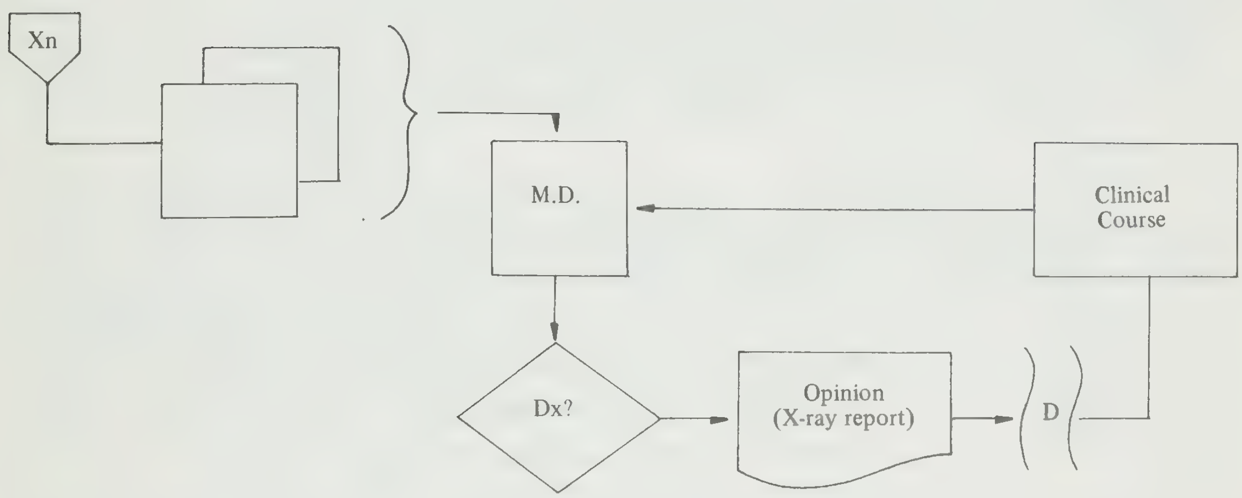
4. Concept of Feedback

Medicine can easily be traced through the recent coat of scientific

components to the traditional art of healing where judgement of the physician was the supreme measure of professional ability. Authority and personality were important ingredients. Introduction of statistical self-evaluation eliminated many ineffective drugs such as strychnine, and autopsies sharpened our diagnostic accuracy. Modern technology reshaped many of our practices, but, due to the lack of adequate data handling practices, we are still making many decisions with no inherent control measures. Let us examine more closely this important deficiency in medicine.



This is a typical design of a practitioner. For instance, the radiologist, in possession of the X-ray data and possibly some other clinical information, after comparing the case with his past experience, MEMORY, decides what the most probable diagnosis is, in his opinion, and issues the X-ray report, OPINION. The design clearly indicates to the student of information systems that this open-ended design is a religious rather than a scientific pattern. The physician of this design declares a dogma rather than submits a scientific evaluation. The following design is more acceptable to the systems analyst:



In this model the radiologist interpreting X-ray findings received the feedback (CLINICAL COURSE) validating the diagnostic prediction or showing the diagnostic error. Currently, the clinical pathological conferences and some follow-up effort as well as clinical research data provide sporadic feedback but not the organized regular evaluation proposed on this model. Systems analysis may be further extended in this direction, and every decision which may be later tested for correctness should be earmarked. At the systems design stage the feedback loop can be inserted whenever applicable, usually with minimal effort. Actually, in our own plans we provide the radiologist not only with the evaluation of his own diagnostic/prognostic statistics, but we place this in perspective by comparing these data with other radiologists' "batting averages." The educational potential of this feedback loop exceeds all our past experience. If this is done tactfully, assuring the clinician of confidential handling of data, the demonstration of errors is perhaps the most effective way toward self-improvement. This model, with some modifications, is readily changeable to·feedback models for all professionals, an all-important feature of systems thinking.

Further development of the emergency loop

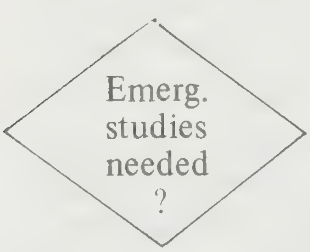
Let us now further examine the outcomes of the decision.

There are three possible outcomes recognized:

(a) no evidence for emergency
(b) emergency present
(c) emergency may be present

From a clinical point of view, (b) and (c) are treated together in the subsequent event flow. The first decision is now: "Is any therapy necessary prior to further data acquisition?" This is a *normative* approach again assigning highest priority to emergency therapy. If the outcome of this decision is a NO, the next decision is essentially closely related: "Is emergency surgery needed?" The answer to this question may be YES (e.g., obvious perforated viscus, or trauma requiring surgery). The patient should be prepared for surgery. This decision contains a gamut of messages to the emergency room nurse, to the admission clerk, to the family, to the operating room personnel, to the anesthesiology department, etc. Systems thinking sheds light on the many directions this decision should be disseminated.

If the answer is doubtful, i.e., the patient may be a candidate for emergency survery but definitive decision cannot be made at this time, the event flow leads to the next decision: "Any emergency studies needed?" This may be only clinical observation, or may cover consultations, X-ray or laboratory studies, in order to remove the uncertainty blocking the road to positive answers. If the answer to this question is YES, acquisition of these data will follow. This again will keep the other members of the emergency room team informed. Without any medical background, the admissions clerk can follow the chain of events.



If the answers to all three decisions comprising the EMERGENCY LOOP are negative, the flow of events requires recording of the decision that NO EMERGENCY IS PRESENT (so that the feedback loop can be established; e.g., if a case of abdominal pain is

admitted by the emergency room resident which later, on the ward, proves to be a perforated viscus, the diagnostic error should be reported by the system to the resident).

The Non-emergency Loop

Once the need for emergency therapy is ruled out, the next decision is implanted to move the procedure to the diagnostic decision as rapidly as possible. Therefore, the next decision is aimed at the surgical resident:

"Do you take full responsibility or do you want consultation?" The purpose of consultation may be:

(a) advice
(b) transfer of the case to another department.

The next decision is: Is hospitalization required? The purpose of this decision is to formalize a decision of great importance with conflicting factors. If medically possible to keep the patient out of the hospital, this should be evaluated critically now. If the surgical resident thinks that hospitalization is necessary, we continue the flowchart by formalizing the RATIONALE of this decision

5. Operational Considerations

The primary function of our Admissions Department is a *sorting* of patients into various groups, viz., those in need of medical advice or emergency treatment, and those requiring hospitalization. To achieve this aim in an optimized fashion, two conflicting considerations must be weighed against each other: (1) the admission procedure should be carried out efficiently and expeditiously, and (2) the data acquired should be adequate for the decisions shown on the flowchart. Obviously, in terms of time, the aim is to *minimize the admission time,* but also to *minimize the risk* of incorrect decisions. The second consideration is to reach a safe diagnosis. The data acquired (3, 15, etc.) should be adequate to reliably rule out the *emergency loop* (4 through 14), make decisions 5 and 6 in a logical fashion, and complete the functions to any of the off-page exit figures.

Systems analysis enabled us to design the flow diagram which is

the presentation of the various *possibilities*. There were, however, no data available as to the *probability* of the various alternate pathways. Actually, there were no good data available on any segment of the flow diagram. Therefore, the computer-oriented programme was planned in stages and the *first stage* was designed to build a *basic* computer-oriented *DATA BASE*. The questionnaire was formulated to accumulate primary data. Once this foundation was available, a more sophisticated second stage could be built on it.

The Initial Data Base

The questionnaire covered the following: (1) The time required for the admission procedure, (2) Is this admission "elective"? (3) Is life-saving emergency present? (4) Emergency studies or therapy needed during the admission procedure? (5) Consultation during admission, (6) Predictions by the admitting surgeon.

(a) "IS THIS AN OBVIOUS SURGERY CANDIDATE?" In addition to this, three other categories were offered on the questionnaire, viz., PROBABLE and POSSIBLE surgery candidate, or NO SURGERY EXPECTED.

(b) In all cases where the surgeon anticipated surgery after admission, the next question offered three categories: RIGHT AWAY, NEXT DAY, or AFTER WORK-UP.*

The completion of this brief form was no noticeable extra burden to the surgeons.

The initial data base revealed that about half of the patients were handled in less than an hour. Interestingly, the admission procedure became progressively slower during the first four months of the observation period. These differences proved statistically significant. Analysis of the data failed to show any apparent correlation between duration of admission and clinical diagnosis. Neither were consultations correlated with slower admissions. Hence, we concluded that factors other than the difficulty of diagnostic decisions must play a major role, e.g., availability of personnel, facilities, etc. The tendential changing pattern from month to month is interpreted as another evidence that the complexity of the diagnostic decisions is not the rate-limiting factor, since the patient material was

* Initially, a fourth category was also included I DON'T KNOW. Soon, we learned, however, that this was an easy way out of the burden of computer-oriented prediction and was used excessively. In the revised questionnaire, we excluded this category.

remarkably similar from month to month. Table 2 shows the summary of some other data.

The powerful, educational impact of monitoring decisions was revealed by the results obtained from the last part of the questionnaire, viz., the predictions: (a) is this case a surgical candidate? (Answer categories: OBVIOUS, PROBABLE, POSSIBLE, or NO CANDIDATE), and (b) when is surgery expected? (Answer categories: RIGHT AWAY, NEXT DAY, AFTER WORK-UP).

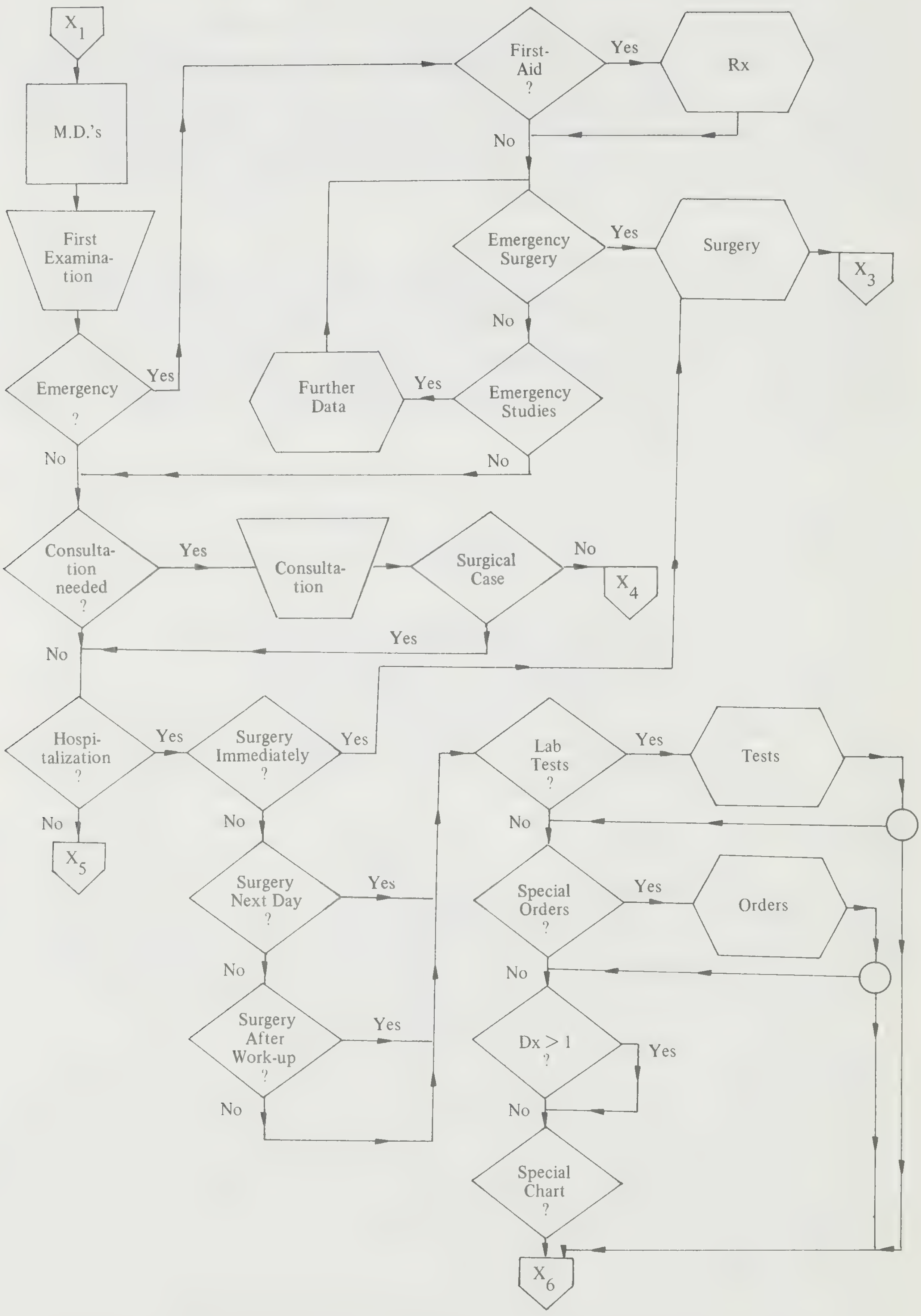
The prediction statistics shown on Table 3 were presented to the surgical staff and had an obvious impact on the quality of subsequent decisions, as evident from Table 3a. This experience was very encouraging, proving that by placing the data capturing system closer to the level of the decision system, we are able to monitor clinical activities effectively.

TABLE 1

MINUTES REQUIRED FOR COMPLETION
OF ADMISSION PROCEDURES

Month	**25% of patients processed within**	**50% of patients processed within**	**75% of patients processed within**
February	32 minutes	55 minutes	87 minutes
March	45 minutes	75 minutes	113 minutes
April	53 minutes	76 minutes	127 minutes
May	55 minutes	87 minutes	142 minutes
June	45 minutes	66 minutes	104 minutes

FLOWCHART X_2



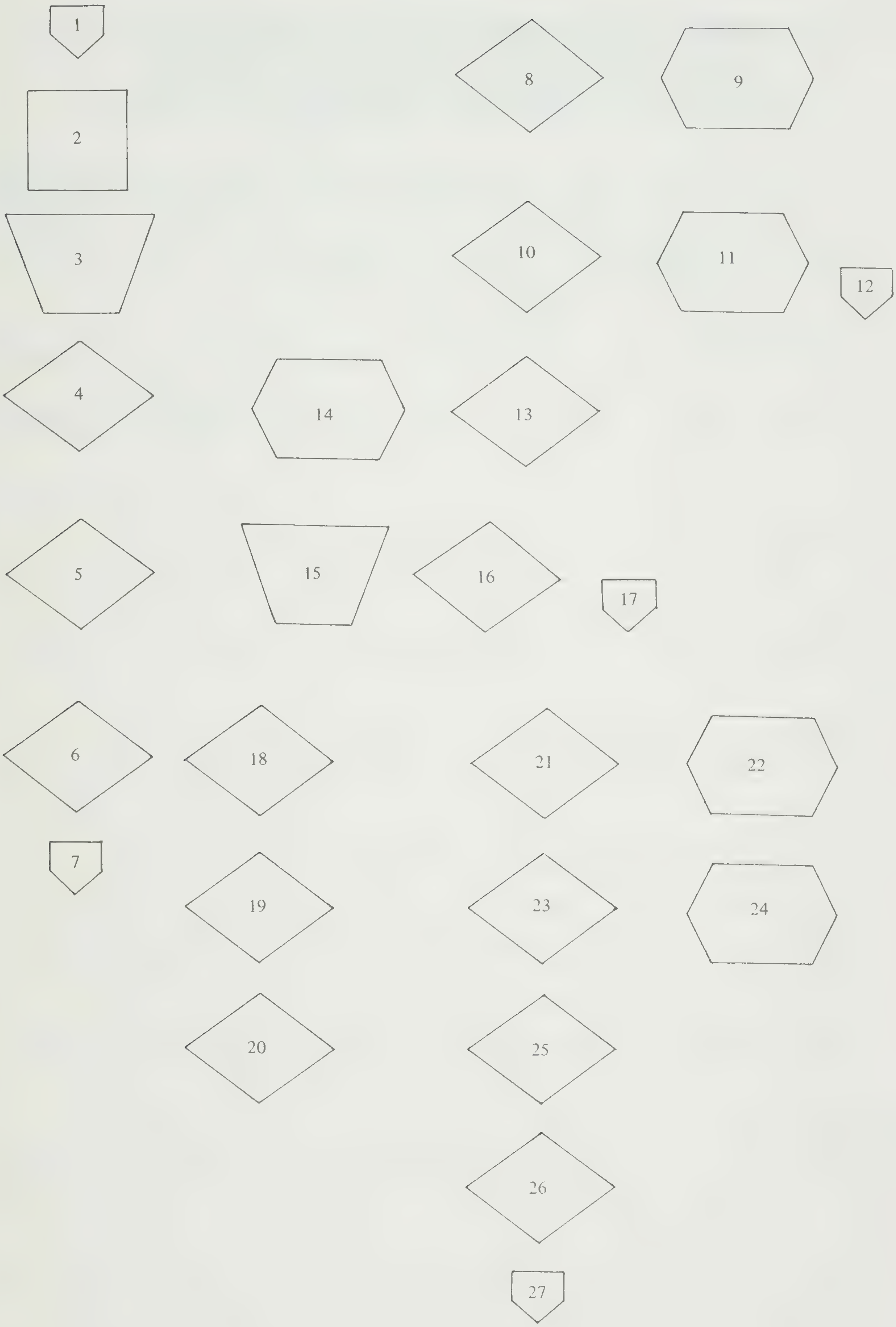

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TABLE 2

STATISTICAL DATA ON GENERAL SURGERY PATIENTS
ADMITTED IN SIX CONSECUTIVE MONTHS
TO THE E. J. MEYER MEMORIAL HOSPITAL

	Feb	Mar	Apr	May	June	July	Average
% Elective Admissions	47	37	40	36	38	51	41.5
% Non-elective Admissions	53	63	60	64	62	49	58.5
% Consultations	11	13	6	9	8	12	9.8
% of Life-saving Emergencies	2.6	3.5	6.7	2.1	2.7	4.3	3.6
% With an Airway Obstruction	0.0	0.0	2.0	0.7	0.6	0.7	0.7
% With a Massive Hemorrhage	1.7	1.4	0.0	0.0	0.0	0.0	0.5
% With Acute Severe Hypoxia	0.0.	0.0	0.0	0.7	0.0	0.8	0.2
% With Shock	0.9	1.4	4.7	0.0	2.0	1.4	1.9
% With a Large Wound	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% With Poisoning	0.0	0.7	0.0	0.7	0.0	1.4	0.5

TABLE 3

PREDICTION BY ADMITTING SURGEON

QUESTION: IS THIS CASE A SURGERY CANDIDATE?

Category Checked	**Per cent Operated**		
	April	May	June
Obvious Candidate	83	83	82
Probable Candidate	50	69	73
Possible Candidate	58	29	33

TABLE 3a

PREDICTION BY ADMITTING SURGEON — WHEN IS SURGERY EXPECTED?

	Day of Surgery Admission Date is Day 1	Category Checked		
		Right Away	Next Day	After Work-up
	1	83%	5%	25%
	2	17%	71%	15%
A	3	–	4%	10%
P	4	–	5%	–
R	5	–	15%	9%
I	6	–	–	15%
L	7	–	–	–
	8	–	–	–
	over	–	–	26%
	1	92%	11%	5%
	2	8%	72%	–
	3	–	11%	40%
M	4	–	–	–
A	5	–	–	7%
Y	6	–	–	6%
	7	–	–	–
	8	–	–	10%
	over	–	–	32%
	1	56%	–	–
	2	33%	65%	9%
J	3	–	6%	37%
U	4	–	–	12%
N	5	–	18%	6%
E	6	–	4%	8%
	7	–	–	7%
	8	–	–	3%
	over	11%	7%	19%

Initial Data Base

For a period of four months, careful analysis of the data was carried out to establish the probability values for the model evolved during the systems analysis plan. These studies showed the following. (See page 158.)

6. Systems Design

The previous pages showed a partial practical demonstration of flowcharting the results of the systems analysis. Pursuing the example of the admission to the surgical department, as the details of the prevailing procedure became clear, the points of data loss and inefficiency also became quite striking. The emergency room nurse makes some important observations presently not recorded. Some of these may be such that the floor nurses could greatly benefit from the records.

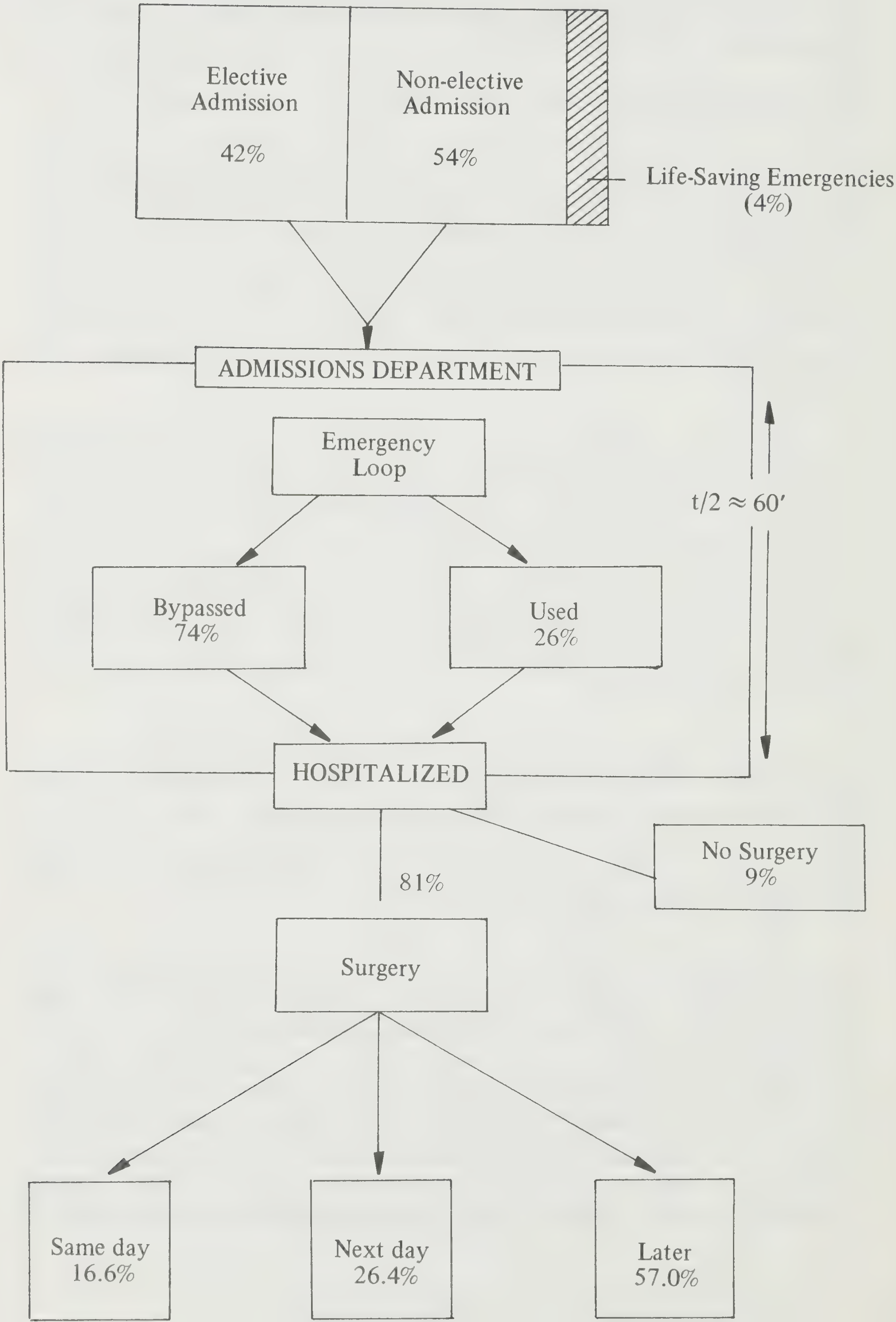
The Social Service may be of great assistance in certain circumstances, but the criteria for immediate notification first must be clearly defined. Also, the criteria for certain emergency procedures need careful definition. For instance, senior staff members mentioned that a spinal tap should never be performed during the admission procedure. If urgent, the patient should be rapidly processed through the admissions department and the lumbar puncture should be done on the ward. This approach can, of course, be built into the system.

Systems design is a joint effort between health professionals and information scientists. The primary planning is clinical; the purpose is optimization of diagnostic and therapeutic plans to achieve maximal efficiency in minimal time. At variance with the operation by evolution, systems design is a *de novo* planning with all available scientific and technical tools.

Information recording is the central issue in the planning. If all health professionals accurately record the data, if the records guide the logic of the record user, if the system provides support in form of statistical summary of past experience, we can expect optimal performance by the fully informed users of the system. If the user knows what the system can provide, the judgement is as good as the individual is able to make. The system should keep all participants at the highest level of cognizance in order to close the gap between potential optimal decisions and actual decisions suboptimal due to

FIGURE 4.

Initial Surgical Data Base



less than maximal cognizance.

Data acquisition design closely follows the flowchart. This process is often referred to as DOCUMENTATION of the flowchart. This is a particularly stimulating part, with the opportunity given to the senior staff to design NORMATIVE rules for the house staff. The residents' objective is to gather practical experience. In a non-system environment, the resident is forced into numerous decisions without a formal set of institutional policies. Learning without such guidelines is inviting errors, and gathering experience through mistakes is a method tolerated by necessity but which can be terminated by a tightly monitored system with lists of data for all decisions and catalogue of all decisions.

The manual 2A will illustrate how the practical documentation of a flowchart is carried out to make the information system technically computer-compatible. It is more important, however, to make the system intellectually a continuous, cohesive thought flow from human to machine and back to human, using the machine only as a vast memory robot under full control of the clinicians and other users.

7. Summary Discussion

Systems thinking is essentially an integration of modern science and technology with clinical medicine. The purpose is to exploit modern sciences for better patient care. Systems thinking is offered to enhance reasoning in medical thinking. For this purpose, the problems have to be formalized. Formal statements are necessary for rational decisions, use of formal logic, statistics, data banks and scientific evidence. Admittedly, many clinical decisions can be equally good without such a supporting body of scientific evidence. We would not even claim that scientifically correct decisions are always the best decisions. Intuitive decisions occasionally may be better. But on a statistical basis, we are convinced that rational decisions using a vast body of past experience will prove far better. Also, the non-system may appear more individualized, both in terms of patients and health professionals. It is, however, an inevitable trend in our evolving society that while our resources are limited, demands for services are steadily increasing. A non-system is a luxury of the past, rapidly becoming a national sin in the future.

Appendix C

GLOSSARY

APPENDIX C

Glossary

The digital computer system with potential applications in "computer medicine" generally consists of a *central processing unit,* the "heart," with built-in magnetic core storage, and arithmetic and logic systems. This system is surrounded by *Input, Output,* and facilities for data conversion with various types of external high character capacity storage.

Access, Random: (1) Pertaining to the process of obtaining information from or placing information into storage where the time required for such access is independent of the location of the information most recently obtained or placed in storage. (2) Pertaining to device in which random access, as defined in definition (1), can be achieved (q.v. photo optical mass memory, data cell, and magnetic disk).

Access, Serial: Pertaining to the sequential process of searching for or entering information into storage such as on a magnetic tape.

Acoustic Coupler: Device which converts an electrical signal (analogue or digital) into an audible tone which can then be transmitted by an ordinary telephone. A second coupler at the receiving station passes the reconverted signal to the computer.

Alphameric Characters (alphanumeric): Characters which may be either letters of the alphabet, numerical digits, or certain special symbols.

Analogue: The representation of numerical quantities by means of continuous physical variables; e.g., rotation, voltage, or resistance.

Audit: Step by step tracing of data from output to input source in order to verify accuracy.

Batch: Technique by which items to be processed must be coded and collected into groups prior to processing.

Binary: A characteristic, property, or condition in which there are but two possible states; e.g., the binary number system using 2 as its base and using only the digits zero (0) and one (1).

Bit: (1) An abbreviation of *binary digit*. (2) A single character in a binary number. (3) A single pulse in a group of pulses. (4) A unit of information capacity of a storage device.

Byte: (1) Generic term to indicate a set of consecutive binary digits; e.g., an 8-bit or 6-bit byte. (2) A group of binary digits usually operated upon as a unit.

Central Processing Unit: Contains the main storage (usually core), arithmetic unit, and special register groups.

Character: (1) One symbol of a set of elementary symbols such as those corresponding to the keys on a typewriter. The symbols usually include the decimal digits 0 through 9, the letters A through Z, punctuation marks, operation symbols, and any other single symbols which a computer may read, store, or write. (2) The electrical, magnetic, or mechanical profile used to represent a character in a computer, and in its various storage and peripheral devices. A character may be represented by a group of other elementary marks such as bits or pulses.

Check, Validity: A check based upon known limits or upon given information or computer results; e.g., a calendar month will not be numbered greater than 12, and a week does not have more than 168 hours.

Code: (1) A system of symbols for meaningful communication. (2) A system of symbols for representing data or *instructions* in a computer or a tabulating machine. (3) To translate a problem into computer readable forms.

Collate: To merge two or more ordered sets of data or cards into one or more ordered sets without changing the original orders of the merged sets.

Compile: Computer translation of a *source language* into *machine language* (see code) by used appropriate programmes.

Compiler: A special computer programme for converting a *source language* into *machine language.*

Computer, Analogue: A computer which represents measurable variables by electrical or other analogies. An analogue computer measures continuously whereas a digital computer counts discretely.

Computer, Digital: A computer which processes information represented by numbers as compared with an *analogue computer* for continuous data. More specifically, it is a device for performing sequences of arithmetic and logical operations.

Conversational Mode: *Real time* interactive process between user and computer where the latter is programmed to react to interrogations and statements of the user, normally through a teletypewriter or a *video display* and keyboard.

Copy, Hard: A printed copy of machine output; e.g., printed reports, listings, documents, and summaries.

Data Bank: A collection of files of information all of which are in machine readable form.

Data Cell: A storage device which houses strips of magnetic film any one of which can be *randomly accessed.* Can store up to 3,200,000,000 *bits* of information.

Data Line: Telephone circuit, teletypewriter circuit, microwave, or other channel over which *digital* or *analogue* data is transmitted.

Debug: (1) To locate and correct any errors in a computer programme. (2) To detect and correct malfunctions in the computer system.

Density: The number of *bytes* per inch stored on magnetic tape. Standard densities are 200, 556, 800 and 1,600 *bytes* per inch.

Digit, Binary: A numeral in the *binary* scale of notation. This digit may be zero (0), or one (1). It may be equivalent to an on or off condition, a yes or a no. Often abbreviated to *bit*.

Digit, Check: One or more redundant digits carried along with a machine byte as a self-checking or error-detecting code to detect malfunctions of equipment in data transfer operations.

Digitize: To convert an instantaneous analogue measurement of a physical variable into a numerical value.

Disk, Magnetic: See Magnetic Disk.

Edit: To rearrange data or information either manually or by processes inherent in computer operation.

Equipment, Input/Output: Equipment used for transferring information in or out of a computer; such as teleprinter, video display, line printer and so forth.

Equipment, Peripheral: Auxiliary machines which may be placed under the control of the central processing unit and which are usually input/output equipment and converters.

File: A collection of records; an organized collection of information directed toward some purpose.

File, Master: A *file* of semipermanent reference information which is usually up-dated periodically.

Hardware: Physical equipment or devices forming a computer and peripheral equipment. Contrast with *software*.

Header: The first section of a record or file which identifies the type and format and other pertinent information relating to the file.

Hollerith: A widely used system of encoding *alphanumeric* information onto cards, hence hollerith cards is synonymous with punch cards.

Index Medicus: A monthly (with annual cumulation) printed listing of articles in over 2,400 medical journals, by subject and author, produced by the National Library of Medicine from *MEDLARS* tapes.

Input: Information or data transferred or to be transferred from an external storage medium into the internal storage of the computer.

Inquiry: A technique whereby the direct interrogation of the contents of a computer's storage may be initiated at a keyboard or other input device. See Conversational Mode.

Instruction: A coded set of characters which causes the central processing unit to perform an operation.

Interrogate: Procedure of searching a *file* to locate and retrieve a particular *record.*

Language: (1) Source language – The original form in which a *programme* is prepared prior to processing by the machine. Examples are Cobol, Fortran, PL1 and so forth. (2) Machine language – The set of instructions expressed in the number system basic to the computer.

Linkage: The operation of relating two or more different types of record pertaining to the same individual, e.g., hospitalization and other medical records.

Loop, Closed: Pertaining to a system with feedback type of control, such that the *output* is used to modify the *input.*

Magnetic Disk: An on-line storage device in which information is recorded on the magnetizable surface of a rotating disk.

Magnetic Drum: An on-line storage device in which information is recorded on the magnetizable surface of a rotating cylinder.

Magnetic Tape: An on-line or *off-line* storage device in which information is recorded on the magnetizable surface of a strip of plastic tape.

Mark Sense: A technique for detecting special pencil marks entered in special places on a punch card or other data forms and automatically translating the marks into code.

Memory: Same as *storage.*

MEDLARS (Medical Literature Analysis and Retrieval System): A

computer-based bibliographical key to the world's Medical Journals, compiled since 1964 by the National Library of Medicine in Bethesda, Maryland.

Mnemonic: An easily remembered code word that stands for a computer instruction, e.g., MPY for multiply.

Off-line: Descriptive of a system and of the peripheral equipment or devices in a system which are not under the control of the *central processing unit.*

On-line: Descriptive of a system and of the peripheral equipment or devices in a system which are under the control of the *central processing unit.*

Output: The information transferred from the internal storage of a computer to secondary or external storage, or to any device outside of the computer.

Photo Optical, Random Access Mass Memory: A storage device which records images of documents (alphameric data, photographs, figures, X-rays, etc.), on microform at the rate of 72 pages per Photo Data Card, the Cards being assembled into units (Foto Data Cells). Modules of these units can store 750,000,000,000 *bits* of information.

Pointer: An indicator within a *record* which gives the location of other related *records.*

Printout: Output of a computer which is printed on single or multicopy paper. Also referred to as *hard copy.*

Processing, Batch: Technique by which items to be processed are coded and collected into groups prior to processing.

Programme, Computer: The complete plan for the solution of a problem, more specifically the complete sequence of instructions and routines necessary to solve a problem.

Random Access: See Access, Random.

Read: (1) To transfer information usually from an input device to main storage. (2) To retrieve data from storage.

Real Time: (1) Pertaining to the actual time during which a physical process takes place. (2) Pertaining to the performance of a computation during a period, short in comparison, with the actual time that the related physical process takes place in order that results of the computations can be used in guiding the physical process.

Record: A group of related facts or fields of information treated as a unit.

Routine: Set of coded *instructions* arranged in proper sequence to direct the central processing unit to perform a desired operation or sequence of operations.

Software: The totality of programmes and routines and their documentation used to extend the capabilities of computers, such as *compilers, library routines,* and so forth.

Storage: A device in which data can be stored and from which it can be obtained at a later time. The means of storing data may be chemical, electrical or mechanical.

Storage, Buffer: (1) An input device in which information is assembled from external or secondary storage and stored ready for transfer to internal storage. (2) An output device into which information is copied from internal storage and held for transfer to secondary or external storage.

Storage, Auxiliary: A storage device in addition to the main storage of a computer, e.g., magnetic tape, disk and drum.

Storage, Main (core): A storage device in which data are represented in a binary form by the direction of magnetization in each unit or an array of magnetic material. Usually the fastest storage device of a computer and the one from which *instructions* are executed.

TELEX, TWX, etc.: Proprietary terms for communication networks comprising teletypewriters and an automatic dial exchange. Messages are typed automatically at the receiving terminal at the same time as they are being sent.

Time-sharing: A method of operation in which a computer facility is shared by several users for different purposes at (apparently) the

same time. Although the computer actually services each user in sequence, the high speed of the computer makes it appear that the users are all handled simultaneously.

Update: To modify a master file according to current information.

Video Display: A cathode ray tube similar to a TV tube on which computer output is displayed in readable form for a user. The display is not permanent but can be regenerated as required.

Word: Ordered set of characters comprising one or more bytes and treated by the *central processor* as a unit.

Write: (1) To transfer information, usually from *main storage,* to an output device. (2) To record data in a storage device.

Appendix D

ABBREVIATIONS

APPENDIX D

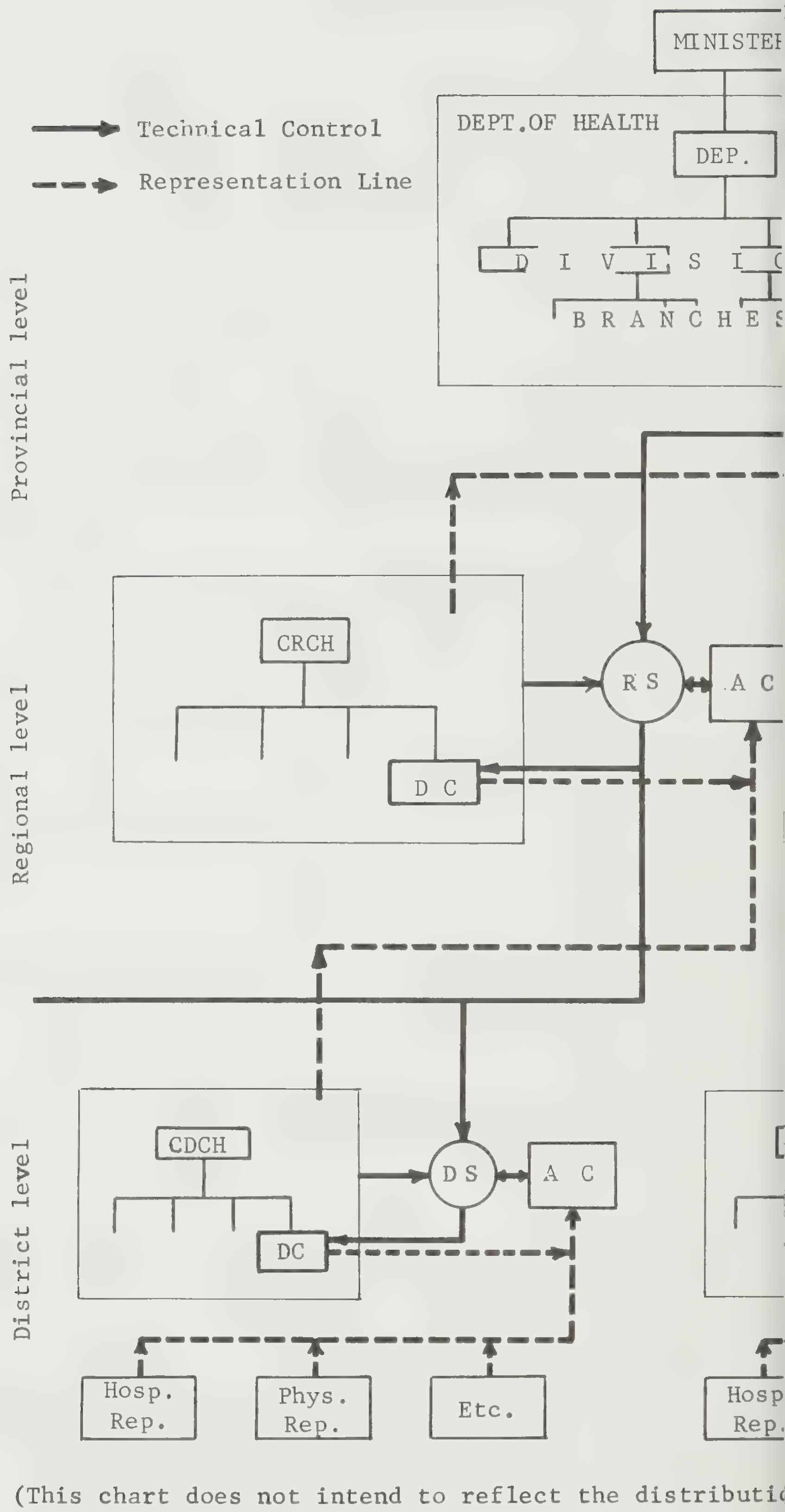
Abbreviations

ASCA	Automatic Subject Citation Alert (Institute for Scientific Information)
BN	Birth Number (as issued by province of birth)
CRT	Cathode Ray Tube
DBS	Dominion Bureau of Statistics
ECG	Electrocardiogram
EDP	Electronic Data Processing
EEG	Electroencephalogram
EMG	Electromyogram
GE	General Electric Corporation
HIRB	Health Insurance Registration Board (of Ontario)
HIS	Health Information System in this report. Usually hospital information system elsewhere.
IBM	International Business Machines Company Limited
ITT	International Telephone and Telegraph Limited

LCC	Linkage Control Centre (page 87)
MEDLARS	Medical Literature Analysis and Retrieval System (see Glossary)
OHIP	Ontario Hospital Insurance Plan
OHSC	Ontario Hospital Services Commission
OHSIP	Ontario Health Services Insurance Plan
OISE	Ontario Institute for Studies in Education
OMA	Ontario Medical Association
OMSID	Ontario Medical Services Insurance Division (of the Department of Health)
OMSIP	Ontario Medical Services Insurance Plan now replaced by OHSIP
PDF	Personal Data Files (page 85)
RCA	Radio Corporation of America
REP	Representative
SIN	Social Insurance Number (issued by the Dominion Government)
TELEX	Trade name for a dial teletypewriter exchange service (Canadian National – Canadian Pacific Telecommunications)
TWX	Trade name for a dial teletypewriter exchange service (Bell Canada)
WHO	World Health Organization

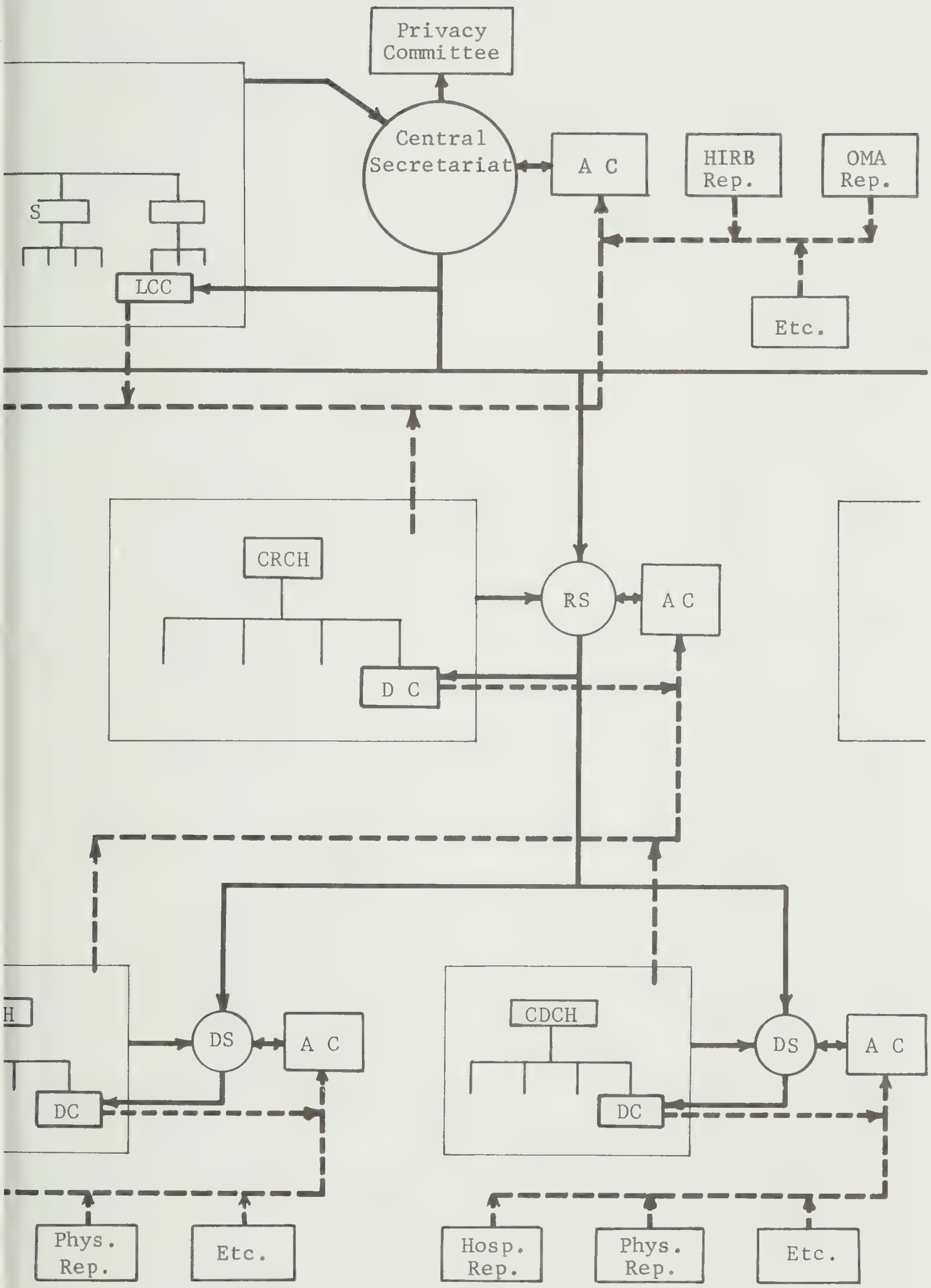
Appendix E

AN ILLUSTRATIVE ORGANIZATION CHART



(This chart does not intend to reflect the distributi

AC Advisory Council
RS Regional Secretariat
DS District Secretariat
CDCH Chairman District Council of Health
CRCH Chairman Regional Council of Health
CS Central Secretariat



f hardware within the network.)

DC   Data Centre
Hosp. Hospital
LCC   Linkage Control Centre
Phys. Physicians
Rep. Representative